

SPECIFICATION

Title of the Invention:

STEREOENDOSCOPE WHEREIN IMAGES HAVING PASSED
THROUGH PLURAL INCIDENT PUPILS ARE TRANSMITTED
BY COMMON RELAY OPTICAL SYSTEMS

Background of the Invention:

Field of the Invention and Description of Related Arts:

This invention relates to a stereoendoscope wherein images having passed through plural incident pupils are transmitted by common relay optical systems so that an observation providing a stereo-feel may be possible.

Recently, particularly in the surgical field, there is noted a so-called endoscope operation wherein, in order to reduce the burden on the patient, without opening the abdomen, a small hole is made in the abdominal part, an endoscope is inserted through the hole for the observation and treatment. In this field, the operation has been already made by directly seeing and stereo-observing the affected part with both eyes and therefore, even in the endoscope operation, the stereo-inspection is strongly desired. If the stereo-inspection can be made, the operation will be easy, the operation time will be reduced and the burden on the patient will be further reduced.

As a stereo-inspection endoscope whereby

stereo-inspection is possible, there is a first related art example suggested in a Japanese patent application No.309078/1992 shown in Fig. 1A wherein two exactly the same optical systems are arranged in parallel and the images formed by the objective optical systems 401 and 401' are transmitted for a predetermined distance by the transmitting optical systems 402 and 402' (in this case, relay lens systems) and are taken by such image taking devices 403 and 403' as CCD's.

The taken pair of the right and left images are converted to electric signals and are displayed in a TV monitor not illustrated. At this time, when the displayed right and left images are switched at a high speed and simultaneously shutter spectacles synchronized with the images are used, the image for the right eye will be observed with the right eye and the image for the left eye will be observed with the left eye so as to be able to be stereo-inspected.

Also, as another type stereoendoscope, there is a second related art example suggested in a Japanese patent application No.28278/1993 shown in Fig. 2A wherein the objective optical system 414 and the relay lens system 415 which is a transmitting optical system are formed of one axially symmetrical optical system. A prism 416 is arranged at the rear end of the relay lens system 415 and a pair of right and left images having a parallax are formed and taken in the the image taking devices 417 and 417' by spatially dividing the pupil into two with the prism. Figs. 1B and 2B on the left side of Figs. 1A and 2A show respective incident pupils.

In order to make a stereo-inspection, it is necessary to obtain a pair of right and left images having a parallax from each other. Therefore, the incident pupil for the right image of the optical system and the incident pupil for the left image must be positioned as spatially separated. Also, the magnitude of the stereo-feel in the case of the stereo-inspection is proportional to the center distance between the right and left incident pupils.

In the two above mentioned related art examples, in the case of the first type in which the same two optical systems are arranged, when the objective optical systems 401 and 401' to the image taking means 403 and 403' are separately formed and the left and right incident pupils 407 and 407' are separately positioned, images having a parallax from each other will be obtained. The center distance d between the left and right incident pupils 407 and 407' coincides with the optical axis distance D between the left and right objective optical systems 407 and 407'.

In the second type in which the pupil is divided among the above mentioned related art, the objective optical system 414 and transmitting optical system 415 are formed of one axially symmetrical optical system and the pupil is one in this part but, when this one pupil is spatially divided into two by the pupil dividing means (in the above mentioned case, the pupil dividing prism) 416 and respective images are produced, images having a parallax from each other will be obtained. The center distance d between the left and

right incident pupils 418 and 418' is $1/2$ the size of the incident pupil 419 of the objective lens.

In the type in which the same two optical systems are arranged, as it is formed of separate right and left parts, the number of the parts is high and the assemblability is low. Also, the magnification difference between the right and left images due to the errors of the respective parts is large, the displacement of the focusing position is large, the normal stereo-inspection can not be made and therefore a fine adjustment is necessary.

In the type of dividing the pupil, there are advantages that the parts common to the right and left light paths are many, the number of parts is low and the displacement of the right and left images can be made little. On the other hand, when compared with the same thickness, the magnitude of the parallax will be smaller than in the first type and a sufficient stereo-feel will be hard to obtain. That is to say, there is a problem that the center distance between the right and left incident pupils is hard to make large. This point shall be explained with reference to Figs. 3A to 4B.

Fig. 3A shows as magnified the objective optical system on the distal end side of the first related art example. Fig. 3B shows its incident pupil. Also, Fig. 4A shows as magnified the objective optical system on the distal end side of the second related art example. Fig. 4B shows its incident pupil.

In the type in which the same two optical systems are arranged, that is, the first related art

example, against the inside diameter ϕ of the objective lens frame 421 of the endoscope distal end 420, the optical axis distance between the right and left objective optical systems is substantially $\phi/2$. Therefore, the center distance between the right and left incident pupils 407 and 407' is also substantially $\phi/2$.

On the other hand, in the type in which the pupil is divided, against the inside diameter ϕ of the objective lens frame 421 at the endoscope distal end 420, the diameter of the incident pupil 419 of the objective optical system is smaller than ϕ , because the incident pupil of the objective optical system is smaller than the pupil of the relay lens system as the NA of the endoscope is limited by the outside diameter of the relay lens system and the picture angle of the objective optical system is larger than of the relay lens system.

Therefore, the center distance between the right and left incident pupils is smaller than $\phi/2$ and is usually about $\phi/6$ to $\phi/10$. Therefore, in this type, the magnitude of the parallax is about $1/3$ that in the above mentioned type. Particularly, in case the distal end is thin, no sufficient stereo-feel will be obtained.

Object and Summary of the Invention:

In view of such circumstances, an object of this invention is to provide a stereoendoscope wherein, as in the type in which the pupil is divided, the parts common to the right and left light paths are made as many as possible, the variations of the right and left images by the production errors or the like can be made few and

images having a stereo-feel by a parallax as large as of the type in which the same two optical systems are arranged are obtained.

The stereoendoscope of the present invention is characterized by comprising an objective optical system which has plural incident pupils formed in different positions and forms plural images having passed through these plural incident pupils and having a parallax from each other and a common image transmitting optical system which transmits the plural images having a parallax from each other.

When thus formed, as the objective optical system has plural independent incident pupils, irrespective of the size of the diameter of the incident pupil of the objective optical system, the parallax will be able to be made large. Also, as the plural images and pupils are not separately transmitted by the plural transmitting systems but are transmitted by the common image transmitting optical system, the number of parts will be able to be reduced. Even if a production error is present in the individual image transmitting optical system, as the images are transmitted by the common image transmitting system, the variation between the plural transmitted images will be able to be reduced.

In order to realize such formation, there are the following two systems (a) and (b):

(a) A formation comprising an objective optical system which forms plural images having parallaxes in spatially separated positions and one image

transmitting optical system which transmits the plural incident pupils and the plural images of the object optical system so that the images transmitted by this image transmitting optical system may be taken finally by one or more image taking means. More concretely, it is as in the following:

A stereoendoscope having an objective optical system, image transmitting optical system and image taking device, characterized in that the objective optical system comprises plural optical systems arranged in parallel and forms plural images having a parallax from each other and the image transmitting optical system comprises an optical system arranged along one optical axis and transmits plural images formed by the objective optical system.

In this formation, as the operation common to (a) and (b) is made and the image transmitted by the image transmitting optical system is also spatially separated, the image can be stereo-inspected through an image taking means taking images or an ocular optical system making observation with the naked eyes. The image taking means can use one or more image taking devices and can take plural images transmitted and spatially separated by the transmitting optical system and stereo-inspection is thereby possible.

The other formation realizing such formation is as follows:

(b) A formation comprising an objective optical system forming plural images having parallaxes where they spatially substantially coincide (superimposed),

jetting pupils corresponding to the plural incident pupils of the objective optical system and one image transmitting optical system transmitting the plural images, wherein the images transmitted by the image transmitting optical system are taken finally by one or more image taking means.

More concretely it is as follows:

A stereoendoscope having an objective optical system, image transmitting optical system and image taking device, characterized in that the objective optical system comprises plural front group optical systems arranged in parallel to take in plural images having a parallax from each other and rear group optical systems arranged so as to be on the same optical axis as of the image transmitting optical system and forming images of beams from the plural front group optical systems where the beams are substantially superimposed and the image transmitting optical system transmits the plural images formed by the rear group optical systems, having a parallax from each other and substantially superimposed and the jetting pupils of the objective optical system.

In this formation, as a common operation is made and images having parallaxes are transmitted to be formed where they are substantially superimposed, the diameter of the relay optical system can be made small.

Brief Description of the Drawings:

Figs. 1A and 1B show a first related art

example. Fig. 1A is a formation view showing its stereoendoscope. Fig. 1B is an explanatory view showing incident pupils.

Figs. 2A and 2B show a second related art example. Fig. 2A is a formation view showing its stereoendoscope. Fig. 2B is an explanatory view showing an incident pupil.

Fig. 3A is a magnified sectioned view of an objective optical system part on the distal end side of the first related art example. Fig. 3B is an explanatory view showing incident pupils of Fig. 3A.

Fig. 4A is a magnified sectioned view of an objective optical system part on the distal end side of the second related art example. Fig. 4B is an explanatory view showing an incident pupil of Fig. 4A.

Figs. 5 and 6 relate to the first embodiment of the present invention. Fig. 5 is a formation view showing the whole of a stereoendoscope apparatus provided with the first embodiment.

Fig. 6 is a formation view showing an image taking optical system in the stereoendoscope of the first embodiment of the present invention.

Fig. 7 is a formation view showing an image taking optical system in the second embodiment of the present invention.

Fig. 8 is a formation view showing an image taking optical system in the third embodiment of the present invention.

Fig. 9 is an explanatory view showing an arrangement example of an image taking device.

Figs. 10A and 10B relate to a modification of the third embodiment. Fig. 10A is an explanatory view showing images formed by an objective optical system and relay optical system and a final image by the image transmission.

Fig. 10B is an explanatory view showing the arrangement of a final image and an image taking device arranged in the position in case the objective optical system and relay optical system of Fig. 10A are used.

Fig. 11 is a formation view showing an image taking optical system in the fourth embodiment of the present invention.

Fig. 12 is a formation view showing an image taking optical system in the fifth embodiment of the present invention.

Fig. 13 is a formation view showing an image taking optical system in the sixth embodiment of the present invention.

Fig. 14 is a formation view showing a main part of an image taking optical system in the seventh embodiment of the present invention.

Figs. 15A and 15B relate to the eighth embodiment of the present invention. Fig. 15A is a plan view showing an objective optical system. Fig. 15B is a side view showing the objective optical system.

Figs. 16A and 16B show the ninth embodiment of the present invention. Fig. 16A is a plan view showing a unit formation of the ninth embodiment.

Fig. 16B is a side view of Fig. 16A.

Figs. 16C and 16D show a first modification of

the ninth embodiment. Fig. 16C is a plan view showing a unit formation of the first modification.

Fig. 16D is a side view of Fig. 16C as an ocular adapter is connected.

Figs. 17A to 17C are explanatory views respectively showing unit formations in the second to fourth modifications of the ninth embodiment.

Figs. 18A to 18E are views respectively showing formations of objective optical system units.

Figs. 19A to 19D are views respectively showing formations of relay optical system units.

Fig. 20 is a formation view showing an image taking optical system in the tenth embodiment of the present invention.

Fig. 21 is a formation view showing an image taking optical system in the eleventh embodiment of the present invention.

Fig. 22 is a formation view showing an image taking optical system in the twelfth embodiment of the present invention.

Figs. 23A to 23D show a meniscus lens in a modification of the twelfth embodiment. Fig. 23A is a sectioned plan view. Fig. 23B is a side view as seen from the side of Fig. 23A. Figs. 23C and 23D are respectively a front view and back view as seen respectively from the front surface and back surface sides.

Fig. 24 is a formation view showing an image taking optical system in the thirteenth embodiment of the present invention.

Fig. 25 is a formation view showing a main part

of an image taking optical system in the fourteenth embodiment of the present invention.

Figs. 26A and 26B show an objective optical system in the fifteenth embodiment of the present invention. Fig. 26A is a plan view. Fig. 26B is a side view.

Figs. 27A and 27B show an objective optical system in a modification of the fifteenth embodiment. Fig. 27A is a plan view. Fig. 27B is a side view.

Figs. 28A and 28B show an image taking optical system in the sixteenth embodiment. Fig. 28A is a plan view. Fig. 28B is a side view.

Figs. 29A and 29B show an image taking optical system in the seventeenth embodiment. Fig. 29A is a plan view. Fig. 29B is a side view.

Figs. 30A to 30G are explanatory views respectively showing unit formations of the eighteenth embodiment.

Fig. 31A to 31F are views respectively showing concrete formations of front group units.

Fig. 32A to 32F are views respectively showing concrete formations of objective optical system units.

Fig. 33A to 32D are sectioned views respectively showing formations of rear group and relay lens system units.

Figs. 34A and 34B relate to the nineteenth embodiment of the present invention. Fig. 34A is a general formation view of a stereoendoscope apparatus provided with the nineteenth embodiment.

Fig. 34B is a view of the arrangement of an

objective optical system on the distal end surface of the stereoendoscope of the nineteenth embodiment.

Figs. 35A to 35C relate to the twentieth embodiment of the present invention. Fig. 35A is a view showing the formation of a stereoendoscope of the twentieth embodiment.

Fig. 35B is an elevation showing the arrangement of an objective optical system as seen from the distal end surface.

Fig. 35C is an explanatory view showing the arrangement of an image taking device as seen from the distal end side.

Figs. 36A to 36F show the formation on the distal end side of the twenty-first embodiment of the present invention. Fig. 36A is a vertically sectioned view. Fig. 36B is an elevation of Fig. 36A.

Fig. 36C is a horizontally sectioned view.

Fig. 36D is an elevation of Fig. 36B.

Fig. 36E is a horizontally sectioned view.

Fig. 36F is an elevation of Fig. 36F.

Figs. 37A and 37B show the formation on the distal end side of the twenty-second embodiment of the present invention. Fig. 37A is a vertically sectioned view. Fig. 37B is an elevation of Fig. 37A.

Figs. 38A and 38B relate to a prior example. Fig. 38A is a formation view showing the formation of an objective optical system in a stereoendoscope of the prior example.

Fig. 38B is an explanatory view of a power arrangement for the objective optical system of Fig. 38A.

Figs. 39 to 42 relate to the twenty-third embodiment of the present invention. Fig. 39 is a general formation view of a stereoendoscope apparatus provided with the twenty-third embodiment.

Fig. 40 is a formation view of an image taking optical system including the objective optical system in the stereoendoscope of the twenty-third embodiment.

Fig. 41 is an explanatory view of a power arrangement of the objective optical system of Fig. 40.

Fig. 42 is a sectioned view showing a frame structure at the distal end of the stereoendoscope in Fig. 39.

Fig. 43 is a formation view of the objective optical system and image transmitting optical system relating to the twenty-fourth embodiment of the present invention.

Fig. 44 is a formation view of the objective optical system in the twenty-fifth embodiment of the present invention.

Fig. 45 is a formation view of the image transmitting optical system including the objective optical system in Fig. 44.

Figs. 46 to 48 relate to the twenty-sixth embodiment. Fig. 46 is a general formation view of an endoscope apparatus.

Fig. 47A is a formation view of a plural visual field direction type endoscope.

Fig. 47B is a view showing the formation of a brightness diaphragm.

Fig. 48 is a formation view of an objective

optical system utilizing a pupil division.

Figs. 49A to 54 relate to the twenty-seventh embodiment. Fig. 49A is a formation view of a plural visual field direction type endoscope including an objective optical system utilizing an eccentric optical system. Fig. 49B is a formation view of an endoscope relating to a modification of the twenty-seventh embodiment.

Fig. 50 is a formation view of an objective optical system in which an eccentric optical system is utilized and an afocal part is partly in common.

Fig. 51 is a formation view of an objective optical system in which an eccentric optical system is utilized and a perspective is made by refraction.

Fig. 52 is a formation view of a design of an objective optical system in which an eccentric optical system is utilized.

Fig. 53 is a formation view of a design in which a relay lens system is combined with an objective optical system.

Fig. 54 is an elevation of an objective optical system having three visual field directions.

Figs. 55 to 58 relate to the twenty-eighth embodiment. Fig. 55 is a formation view of a plural visual field direction type endoscope having a pupil switching apparatus.

Figs. 56A and 56B are formation views of a plural visual field direction type endoscope in which the visual field direction can be switched by an image rotator.

Fig. 57 is a formation view of a plural visual field direction type endoscope in which the visual field direction can be switched by the movement of a solid state image taking device or the like.

Fig. 58A is a formation view of a plural visual field direction type endoscope in which a pupil switching apparatus is provided near the pupil of an objective optical system.

Fig. 58B is a formation view of a plural visual field direction type endoscope different from that of Fig. 58A.

Fig. 59A is a formation view of a plural visual field direction type endoscope relating to the twenty-ninth embodiment. Fig. 59B is a formation view of an endoscope in which the objective optical system is made partly common.

Fig. 60A is a formation view of an optical system of a plural visual field direction type endoscope of the thirtieth embodiment.

Fig. 60B is a formation view of an optical system of a plural visual field direction type endoscope of a modification of the thirtieth embodiment.

Fig. 61A is a formation view of an optical system of a plural visual field direction type endoscope of the thirty-first embodiment.

Fig. 61B is a formation view of an optical system of a plural visual field direction type endoscope of a modification of the thirty-first embodiment.

Description of the Preferred Embodiments:

The present invention shall be concretely explained in the following with reference to the drawings. The stereoendoscope in each of the first embodiment to the twenty-second embodiment is characterized by having an objective optical system which has plural incident pupils formed in different positions and forms plural images having passed through these plural incident pupils and having a parallax from each other and a common image transmitting optical system which transmits the plural images having a parallax from each other.

Each of the first embodiment to the modification of the ninth embodiment is of the formation (a). That is to say, images having a parallax from each other are formed in separated positions by plural objective optical systems arranged at the distal end of an endoscope and the images separated from each other are transmitted by one image transmitting optical system becoming common.

As shown in Fig. 5, a stereoendoscope apparatus 1 comprises a stereoendoscope 2 of the first embodiment having an image taking optical system for stereo-inspection built-in, a light source apparatus 3 feeding an illuminating light to an illuminating light transmitting means provided in this stereoendoscope to transmit the illuminating light, a camera controlling unit (abbreviated as a CCU hereinafter) 4 processing signals for an image taking means built-in in this stereoendoscope 2, a scan converter 5 converting the signal from this CCU 4 to a video signal, a color monitor

6 displaying the video signal put out of this scan converter 5 and shutter spectacles 27 having a shutter function for stereo-inspecting the image displayed in this color monitor 6.

The stereoendoscope 2 has an elongate inserted section 11 to be inserted into a body cavity or the like and a gripped section formed to be large in the diameter at the proximal end of this inserted section so as to be gripped by the operator. This inserted section 11 is formed of a cylindrical rigid jacket tube made of such metal as stainless steel. That is to say, this stereoendoscope 2 is a rigid endoscope having the rigid inserted section 11.

The same as an ordinary endoscope, this stereoendoscope has an illuminating light transmitting means transmitting the illuminating light fed from the light source apparatus 3, an illuminating optical system projecting this transmitted illuminating light out of an illuminating window and illuminating the object side and an observing optical system obtaining two images having a parallax so that the object illuminated by this illuminating optical system may be stereo-inspected.

By the way, in this specification, this observing optical system is mostly explained in an embodiment acting to form two images having a parallax on an image taking device provided with a photoelectrically converting function and is therefore also called an image taking optical system.

The gripped section 12 is provided with a light guide mouthpiece 13 and a light guide connector 15 at the

other end of a light guide cable 14 removably connected at one end to this light guide mouthpiece 13 is removably connected to the light source apparatus 3.

A lamp 16 generating a white illuminating light and a lens 17 condensing this white light are arranged within the light source apparatus 3. The illuminating light condensed by this lens 17 is radiated on the end surface of the light guide connector 15, the illuminating light radiated on this end surface is transmitted by the light guide within the light guide cable 14 and the transmitted illuminating light is fed to the light guide 18 side within the stereoendoscope 2 from the light guide mouthpiece 13.

The light guide 18 as an illuminating light transmitting means is bent within the gripped section 12 and is inserted through the inserted section 11. This light guide 18 transmits the fed illuminating light and projects the illuminating light forward from the distal end surface fixed to the distal end 19 of the inserted section 11 and further through an illuminating lens 20 fitted to an illuminating window.

The respective optical images (represented by reference numerals 7a and 7b in Fig. 6) of the object (represented by the arrow in Fig. 5) 29 illuminated by this illuminating light are formed in image forming positions by objective optical systems 21a and 21b fitted to two observing windows arranged adjacently to the illuminating window within the distal end 19. The two objective optical systems 21a and 21b are of the same formation and are formed of optical lenses preferably of

the same characteristics.

As shown in Fig. 5, the two objective optical systems 21a and 21b have the respective optical axes Oa and Ob in parallel with the center axis of the inserted section, are arranged in parallel on both sides of this center axis and are separated from each other by d in the distance (interval) between both optical axes Oa and Ob. Also, both optical axes Oa and Ob are arranged as separated in the diametral direction crossing the center axis and are therefore arranged symmetrically with the center axis. Two optical images large in the parallax can be formed by the objective optical systems 21a and 21b of the same formation with the optical axes arranged in parallel as separated by the distance d between them.

The images 7a and 7b are formed, as shown in Fig. 6, in separate positions by the two objective optical systems 21a and 21b and are transmitted rearward by a common relay optical system 22, that is, one image transmitting optical system or image transmitting means.

These images are equimultiply transmitted rearward by this relay optical system 22 and finally the same images 10a and 10b as the two images 7a and 7b by the two objective optical systems 21a and 21b are separately formed on a photoelectrically converting surface (image taking surface) of an image taking device 23 arranged within the gripped section 12. For example, in Fig. 5, if the separating direction in the two objective optical systems 21a and 21b is a horizontal direction, two images 10a and 10b will be separately formed in the horizontal direction on the image taking

surface of the image taking device 23.

As shown in Fig. 5, the image taking device 23 has, for example, a square image taking surface and is arranged so that the vertical or horizontal direction of this image taking surface may coincide with the horizontal direction in which the two objective optical systems 21a and 21b are arranged as separated and the center of the image taking surface may be on the optical axis of the relay optical system.

By the way, the light guide 18 inserted through the inserted section 1 may be inserted through outside the relay optical system 22 (for example, like a ring). As shown in Fig. 5, a part of the vertical direction intersecting at right angles with the horizontal direction of the relay optical system 22 may be contained in an incised groove formed by incising in the axial direction a part of the vertical direction intersecting at right angles with the horizontal direction of the relay optical system 22. (One incised groove is shown in Fig. 5 but two incised grooves may be formed in the vertical direction.) When such incised groove is formed, the part which does not in principle substantially contribute to image transmission will be deleted, the image transmitting function will not be reduced, the illuminating light will be able to be transmitted and the inserted section 11 will be able to be made small in the diameter.

As the effective sectioned area of the relay optical system can be made large, the eccentricity (the distance d between the optical axes) of the two objective

optical systems 21a and 21b arranged as opposed to each other eccentrically in the horizontal direction from the optical axis of this relay optical system 22 at the front end of this relay optical system 22, that is, the parallax will be able to be made large and the stereo-inspecting function will be able to be improved. Further, there is a function of reducing the superimposing (cross talk) of two images.

The gripped section can be fittably separated into the output section 24 in which the image taking device 23 is built-in and the input section 25 on its forward side. The input section 25 has an image taking optical system (observing optical system) comprising the two objective optical series 21a and 21b and relay optical system 22.

By making the output section 24 separable, there is made a flexible structure wherein the failing image taking device 23 can be easily repaired or can be replaced with one high in the sensitivity or the number of pixels to improve the performance and an ocular adapter can be connected to make stereo-inspection with the naked eyes. (The structure shown in the later described Fig. 19 may be adopted for the structure of the connecting part.)

The image taking device 23 is extended out of the rear end of the output section 24 and is connected with the CCU 4 through the signal cable 26 and the image taking signal photoelectrically converted by the image taking device 23 is processed. The image signal processed by this CCU 4 is further put into the scan converter 5,

is converted to a video signal and is then put out to the color monitor 6. Two images corresponding to the optical images formed by the two objective optical systems 21a and 21b are alternately displayed in this color monitor 6. By observing the images of the color monitor 6 with shutter spectacles 27, the operator can stereo-inspect the images.

Fig. 6 shows the formations of the image taking optical systems, that is, the two objective optical systems 21a and 21b and relay optical system in the stereoendoscope 2 of the first embodiment.

The images 7a and 7b having a parallax from each other are formed by the plural (two in this embodiment) independent objective optical systems 21a and 21b arranged in the distal end section 19. These images 7a and 7b separated from each other are transmitted by the relay optical system 22 as one image transmitting optical system.

As shown in Fig. 6, the objective optical systems 21a and 21b, for example, the three relay lens systems 22a, 22b and 22c forming the relay optical system 22 and the image taking device 23 having a function of photoelectrically converting optical images are arranged in the order mentioned from the object side. The two images 7a and 7b having a parallax are formed in the spatially separated positions (in this case, in the positions separated from each other in the horizontal direction) by the objective optical systems 21a and 21b of the same formation arranged in parallel as separated from each other by d (for example, $d = 4 \text{ mm}$) of the

distance between their optical axes.

The images 7a and 7b are equimultiply relayed by the relay lens systems 22a, 22b and 22c of the same formation arranged in series so that the optical axes may coincide with each other. That is to say, the images 7a and 7b formed on both left and right sides of the optical axis 0 of the relay optical system 22 (by the objective optical systems 21a and 21b arranged eccentrically on the left and right from this optical axis 0) respectively form images 8a and 8b respectively on both right and left sides of this optical axis 0 in the rear side positions of the optical axis 0 by the relay lens system 22a. These images 8a and 8b respectively form images 9a and 9b on both left and right sides of this optical axis 0 in the rear side positions of the optical axis 0 by the relay lens system 22b. These images 9a and 9b respectively form images 10a and 10b on both right and left sides of this optical axis 0 in the rear side positions of the optical axis 0 by the relay lens system 22c.

In this position, the image taking surface of the image taking device 23 is arranged and the images 10a and 10b are photoelectrically converted and put out. A masking means is provided so that the two images 10a and 10b on this image taking surface may not be superimposed. (As shown in the later described Fig. 8, for example, a visual field diaphragm 30 may be provided on the image forming surfaces of the objective optical systems 21a and 21b to limit the visual field. The invention is not limited to this. (The visual field diaphragm may be provided, for example, in the image forming position in

the relay optical system 22.)

The optical axes 0 of the relay lens systems 22a, 22b and 22c are respectively eccentric by the same amount on the right and left from the optical axes 0a and 0b of the objective optical systems 21a and 21b. The eccentricity can be selected in conformity with the desired parallax magnitude, that is, stereo-feel size and is $d/2$ (for example, $d/2 = 2$ mm) in this embodiment.

The number of relaying times is three times in this embodiment but can be set multiply from one time to ten and several times depending on such specification as the brightness of the optical system.

By the way, in Fig. 6, the reference numerals 28a and 28b respectively represent the positions of the incident pupils of the left and right objective optical systems 21a and 21b and the left and right images 7a and 7b are formed of the lights incident through the respective incident pupils 28a and 28b. The respective incident pupils 28a and 28b are transmitted by the relay lens systems 22a, 22b and 22c forming the relay optical system 22.

During the transmission by the relay lens systems 22a, 22b and 22c, the two pupils may be horizontally displaced but the relay lens systems 22a, 22b and 22c had better be superimposed in order to be made small. Therefor, it is preferable that the two objective optical systems 21a and 21b are respectively formed to be telecentric optical systems, that is, the projecting pupils are formed to be infinitely far.

By the way, the magnitude of the parallax, that

is, the center distance between the left and right incident pupils 28a and 28b is determined by the distance d between the optical axes 0a and 0b of the objective optical systems 21a and 21b and is independent of the brightness of the optical system.

According to this embodiment, as the relay optical system 22 is made common, the trouble of adjusting the lenses can be more extremely omitted than in the case that it is not made common (in the first related art) and a favorable stereo-observation can be made.

Also, as can be judged from Fig. 5, as an image having a parallax can be obtained by arranging the two objective optical systems 21a and 21b as separated from each other, the parallax can be made larger than in the case of using a common objective optical system (in the second related art) and therefore the function of obtaining a stereo-feel can be made large. (The same stereo-feel as in the case that two optical systems are arranged as in the first related art can be obtained.)

Therefore, according to this embodiment, the common optical components can be made few, the adjusted parts can be made few, the cost can be made low and the image having the same stereo-feel as in the case that two optical systems are arranged in the related art can be obtained.

As the two images 7a and 7b having a parallax are transmitted by the relay lens systems 22a, 22b and 22c used in common with the axially symmetrical one, during the transmission, the qualities (the magnification,

MTF, image position, chromatic aberration, coloring and the like) of the two images will lag little during the transmission.

That is to say, even if the individual characteristics of the relay lens system 22a and the others are dispersed by the production error, in this embodiment, as the left and right images are transmitted by the common relay lens system 22a and the others, the influence of the individual dispersion will not be substantially received. Therefore, the left and right images obtained by this embodiment will be images of a good quality having little lag.

In case an operation is made under the observation with this stereoendoscope, a good picture quality and a sufficient stereo-feel will be obtained, a picture image of an observation close to directly observing the affected part will be able to be realized and therefore an environment in which the operation is easy to make will be able to be provided.

Also, in this embodiment, as the left and right images 7a and 7b are formed in the positions spatially separated by the objective optical systems 21a and 21b and are formed in the positions spatially separated by the common relay optical system 22, therefore a stereo-inspection will be able to be made with the image taking device or the like without using an image separating means newly spatially separating the images.

Also, in this embodiment, the final images 10a and 10b by the relay lens system 22c are taken by one image taking device 23. Therefore, the output section 24

is very simplified in the structure and a light weight stereoendoscope can be realized.

By the way, the image taking device 23 may be any of various solid state image taking devices (known generally by the names of CCD, PCD, CMD, AMI and SIT) and image taking tubes (known generally by the names of Sachicon, Busicon and HARP TUBE).

Also, the sensitivity may be improved by utilizing an image intensifier or the like.

The image taking device 23 may be a device for taking color images with a single plate or may take colored images with a formation as a 2-plate or 3-plate camera. Also, as shown in Fig. 6, the final images 10a and 10b by the relay lens system 22c are taken by the common image taking device 23 to reduce the cost and weight.

In order that a stereo-feel optimum to the desire or operation type of the operator may be obtained, the distance between the respective optical axes of the two objective optical systems 21a and 21b may be made variable so that the magnitude of the parallax may be variable.

In this case, in order that the distal end section 19 may be made small, the two objective optical systems 21a and 21b may be made movable to the side opposite to each other in the horizontal direction vertical to the optical axis O of the relay lens systems 22a, 22b and 22c. However, in this case, when the objective optical systems 21a and 21b move, the final images 10a and 10b will be also moved by the relay lens system 22c and therefore, in case the image taking device

23 is fixed, the movement will be limited to be within the image taking range.

By the way, it has been explained that the image taking surface of the image taking device 23 is square. However, a rectangular surface long in the horizontal direction in which the objective optical systems 21a and 21b are arranged as separated may be used. In this case, the image taking range in which the image having a parallax is obtained will be able to be substantially expanded.

By the way, in Fig.. 5 is adopted a simultaneous illuminating and image taking system wherein a color image is taken by using the image taking device 23 in which such color separating filter as a mosaic filter is arranged under a white color light illumination. However, the invention is not limited to this. A surface sequent image taking system wherein a color image is taken by obtaining such color component image as of three primary colors by taking an image with an image taking device having no color separating filter under a surface sequent illumination in which illuminating lights of such wavelength ranges as of red, green and blue are sequentially emitted on the object side will also do.

By the way, in the first embodiment, instead of connecting the output section to the input section 25, an ocular adapter 45' shown in the later described Fig. 16D is fitted so that the stereo-inspection may be made with the naked eyes. In this case, it is preferable to set the number of relaying times by the relay optical system 22

at an even number of times so that the left and right images 7a and 7b by the objective optical systems 21a and 21b may be respectively observed with the left and right ocular lenses. (In Fig. 16D, the number of relaying times is four times.)

By the way, the lens data of the first embodiment are as in Table 1 shown at last in the specification. Fig. 2 and others are collectively shown after Fig. 1. In Tables 1 to 14, r_1 , r_2 , ..., represent radii of curvatures of respective surfaces, d_1 , d_2 , ..., represent surface distances, n_1 , n_2 , ..., represent refractive indices of respective lenses and ν_1 , ν_2 , ..., represent Abbe numbers of respective lenses.

In the following, the second to ninth embodiments are modifications of the first embodiment and, the same as in the first embodiment, the image having a parallax is formed in a position spatially separated by the objective optical systems 21a and 21b.

Fig. 7 shows a structure near the final images 10a and 10b of the relay lens system 22c of the image taking optical system in the stereoendoscope of the second embodiment of the present invention. The final images 10a and 10b are respectively taken by the two image taking devices 23a and 23b. Signal lines (not illustrated) are connected respectively to the two image taking devices 23a and 23b and are connected to a CCU partly different in the internal formation from the CCU 4 in Fig. 5. The others are of the same formation as of the stereoendoscope 2 of the first embodiment.

By the way, in the CCU processing signals for

the two image taking devices 23a and 23b, the same driving signal may be simultaneously applied, for example, to the two image taking devices 23a and 23b, may be simultaneously read out and may be memorized respectively in two frame memories. The same driving signal may be applied alternately respectively to the two image taking devices 23a and 23b and may be read out alternately and the image signal read out may be memorized alternately in the two frame memories.

The image signal simultaneously or alternately memorized in the two frame memories are alternately read out by the scan converter and are alternately displayed in the color monitor. The operator wears shutter spectacles 27 and can observe and stereo-inspect the image displayed in the color monitor 6.

The stereoendoscope apparatus provided with this second embodiment can be realized in substantially the same formation as of the stereoendoscope apparatus 1 in Fig. 5.

This second embodiment has an advantage that the image taking devices 23a and 23b can be focused respectively independently. If they are precisely adjusted, an image higher in the quality than in the case of a common image taking device 23 will be able to be made.

Also, the parallax can be made variable the same as in the first embodiment. However, this embodiment has an advantage that, when the left and right image taking devices 23a and 23b are moved as operatively connected with the movement of the objective optical

systems 21a and 21b, the movement will not be restricted to be within the image taking range in the case of the common image taking device 23.

That is to say, in the first embodiment, as the image taking device 23 is common, the moving range of the left and right images 10a and 10b is restricted to be within the image taking range. However, according to the present embodiment, in case the final images 10a and 10b are fixed, when the movement deviates (separates) from the imaging range, the two image taking devices 23a and 23b will be moved horizontally as operatively connected with the movement of the objective optical systems 21a and 21b and the final images 10a and 10b will be able to be maintained within the image taking range of the respective image taking devices 23a and 23b.

Therefore, there is a merit that a stereo-endoscope in which an image having a stereo-feel is obtained can be realized. The others have the same effects as in the first embodiment. By the way, the lens data of the second embodiment are the same as of the first embodiment.

Figs. 8 and 9 relate to the third embodiment of the present invention. Fig. 8 shows an image taking optical system in the third embodiment. Fig. 9 shows as magnified the arrangement of the image taking devices 23a and 23b. In this embodiment, the two image taking devices 23a and 23b are used the same as in the second embodiment and the light receiving surfaces of the image taking devices 23a and 23b arranged not vertically to the optical axis O of the relay optical system 22 but as

inclined from the vertical direction. In other words, in the central part of the light receiving surface of each of the image taking devices 23a and 23b, the optical axis vertical to this light receiving surface is arranged not to be parallel with the optical axis 0 of the relay optical system 22 but to make an angle larger than 0.

That is to say, when the light receiving surface of each of the two image taking devices 23a and 23b is arranged as inclined in conformity with the image surface curvature aberration 10c generated by the relay lens systems 22a, 22b and 22c and shown in Fig. 2, the deterioration of the image by the curvature aberration will be controlled or reduced.

As the petzval of the relay lens systems 22a, 22b and 22c is positive, even if the image surface by the objective optical systems 21a and 21b is flat, in the case of the transmission by the relay lens systems 22a, 22b and 22c, the image surface will bend on the curved surface with the concave surface directed to the objective side.

Therefore, with the image taking surface or light receiving surface left to be arranged vertically to the optical axis of the relay lens systems 22a, 22b and 22c, a partial fog will be likely to be produced and it will be difficult to keep all the image taking surface focused.

Therefore, in the third embodiment, as shown in Fig. 9, the light receiving surface is arranged as inclined in conformity with the contact surface of the curved image surface. In Fig. 9, the light receiving

surface is inclined by 25.332 degrees to the surface vertical to the optical axis of the relay lens system 22c.

According to this third embodiment, not only the effects of the second embodiment are retained but also a picture image having little curvature aberration is obtained. By the way, the lens data of the third embodiment are as in Table 2.

By the way, as the petzval sum of the relay lens systems 22a, 22b and 22c is a positive value, the petzval sum of the objective optical systems 21a and 21b may be made a negative value to control the image surface curvature aberration of the final images 10a and 10b having passed through the relay lens system 22c.

Figs. 10A and 10B are of modifications showing this manner.

As shown in Fig. 10A, the petzval sum of the objective optical systems 21a and 21b is made a negative value to form images 7a and 7b becoming concave on the rear side (the local radius of curvature of each image surface shall be represented by R). In case the image on the flat image surface is transmitted by the relay lens systems 22a, 22b and 22c, the local radius of curvature of the image surface of the final images 23a and 23b is represented by R' and, as shown in Fig. 10, the light receiving surfaces of the image taking devices 23a and 23b are arranged on the contact surface of the curved surface of a local curvature $1/R'' = 1/R - 1/R'$, the influence of the image surface curvature aberration will be further controlled by this embodiment than by the third embodiment.

By the way, in this case, $1/R - 1/R' = 0$ or the absolute value of $1/R - 1/R'$ may be made small.

Fig. 11 shows an image taking optical system in the fourth embodiment. The final images 10a and 10b of the relay lens system are relayed once more by adapter lens systems 32a and 32b forming an adapter optical system to connect images 36a and 36b and these images 36a and 36b are taken respectively by image taking devices 33a and 33b.

The adapter lens systems 32a and 32b are formed respectively of mirror parts 34a and 34b and lens parts 35a and 35b, a beam is parallel moved outside by the mirror parts 34a and 34b (in this embodiment, the displacement L is 6 mm) and the lens parts 35a and 35b act to re-form the final images 10a and 10b of the relay lens system at any magnification.

The optical axis of each of the lens parts 35a and 35b is eccentric by $d/2$ (2 mm) from the optical axis of the relay lens system 22c except the parallel moved part by the mirror parts 34a and 34b.

In this embodiment, when the parallel moving distance in the mirror sections 34a and 34b and the magnification in the lens sections 35a and 35b are properly set, images 36a and 36b optimum to any size image taking devices 33a and 33b will be able to be obtained.

Also, as the image taking devices 33a and 33b larger in the size than in the first and second embodiments can be used, those larger in the number of pixels in response to the size can be used and a

favorable stereo-observed image high in the resolving degree can be obtained. The others have the same effects as in the second embodiment. The lens data of this embodiment are as in Table 3.

Fig. 12 shows an image taking optical system in the fifth embodiment. This embodiment is an improvement of the fourth embodiment.

The images 36a and 36b are respectively formed by relaying further once the final images 10a and 10b of the relay lens system with the common adapter optical system 32 formed of one lens system and are taken by the image taking devices 33a and 33b. The adapter optical system 32 is formed of a lens system arranged so as to be of the same optical axis as of the relay lens systems 22a, 22b and 22c, the final images 10a and 10b of the relay lens system are formed again at any magnification and the image taking devices 33a and 33b are arranged in the image forming positions.

In this embodiment, the formation can be made simpler by the part having no mirror section within the adapter optical system 32 and has the operations and effects of the fourth embodiment. That is to say, when the magnification of the adapter optical system 32 is optionally set, the images 36a and 36b optimum to the image taking devices 33a and 33b of any size will be able to be obtained.

Also, in this embodiment, the same as in the third embodiment, the light receiving surface of each of the image taking devices 33a and 33b is inclined in conformity with the image surface curvature aberration

generated by the relay lens systems 22a, 22b and 22c and adapter optical system 32 to control the deterioration of the image. In Fig. 12, the light receiving surface is arranged as inclined by 11.902 degrees to the surface vertical to the optical axis of the relay lens system 22c. The lens data of this embodiment are as in Table 4.

Fig. 13 shows an image taking optical system in the sixth embodiment.

The final images 10a and 10b of the relay lens system are further once relayed by the adapter lens systems 32a and 32b forming the adapter optical system 32 and are taken by the image taking devices 33a and 33b. The adapter optical system 32 is formed of the two inclined adapter lens systems 32a and 32b of the same formation. One lens system 32b and the image taking device 33b are parallel eccentric by $d/2$ ($= 2 \text{ mm}$) from the optical axis of the relay lens system 22c and are then inclined by 10.076 degrees with the point at which the optical axis of the lens system 32b intersects with the final image 10b of the relay lens system 22c as a center. The lens system 32a illustrated by the two-point chain lines is also arranged as inclined the same on the opposite side of the optical axis of the relay lens system 22c.

In this embodiment, too, the same as in the fifth embodiment, no mirror section is present and, by freely setting the magnification of the adapter optical system, the images 36a and 36b optimum to the image taking device of any size can be obtained. That is to say, this embodiment has substantially the same effects as of the fifth embodiment. The lens data of this

embodiment are as in Table 5.

Fig. 14 shows a main part of an image taking optical system in the seventh embodiment of the present invention.

The final images 10a and 10b of the relay lens system are further once relayed by the adapter optical system 32 and are formed in the same positions and the common image taking device 33 is arranged in the image forming position in the formation.

In the adapter optical system 32, the final images 10a and 10b of the relay lens system are led to the shutter means 37e side through an optical axis distance extending means comprising respectively lenses 37a and 37b and prisms 37c and 37d and are led to the opposed lens 37f and 37g side so that, when one is shielding light, the other will be passing light. A beam having passed through the lens 37f arranged as opposed to one side of the shutter means 37e passes through the prism 37h, half prism 37i and lens 37j and forms an image 36a in the position in which the image taking device 33 is arranged.

Also, a beam having passed through the lens 37g arranged as opposed to the other side of the shutter means 37e passes through the optical device 37k, half prism 37i and lens 37j and forms an image 36b in the position in which the image taking device 33 is arranged.

In this embodiment, the relayed images 36a and 36b are formed in the same position and are taken by one image taking device 33. The shutter means 37e is arranged on the way of the adapter optical system 32 and

alternately shields the beam so that two images may not be simultaneously formed by the image taking device 33.

This embodiment has an advantage that one image taking device 33 will do and the cost can be reduced. The others have the same effects as of the fourth embodiment.

Figs. 15A and 15B show a formation of an objective optical system in the eighth embodiment of the present invention.

In this embodiment, an objective optical system is formed of perspective objective optical systems 39a and 39b having a perspective front as a visual field.

In this embodiment, a beam incident from the diagonal front side is reflected by using reflecting prisms 40a and 40b as visual field direction changing means and is changed to be in a direction parallel to the optical axis O of the relay optical system 22 (Figs. 15A and 15B show only a part of the relay lens system 22a). In this embodiment, the visual field direction is 45 degrees with the lengthwise direction (the optical axis direction of the relay optical system 22) of the inserted section. The reflecting prisms 40a and 40b may be two separate bodies or one integral body.

The rear side formation of the relay optical system 22 may be the formation of any of the first to sixth embodiments. This embodiment has the same effects as of the first to seventh embodiments except that the visual field direction is different.

Otherwise than the eighth embodiment, the visual field direction can be varied by varying the angles of the reflecting prisms 40a and 40b. Also, if the

objective optical system parts are replaceably formed, various visual field directions, visual field angles and parallaxes will be able to be obtained by replacing only the objective optical system.

Figs. 16A to 16D show the ninth embodiment of the present invention and a unit formation in its first modification.

The stereoendoscope 41 of the ninth embodiment shown in Fig. 16A comprises an objective optical system unit 42, relay optical system unit 43, adapter optical system unit 44 and image taking device unit 45.

The objective optical system unit 42 has objective optical systems 21a and 21b of uniform optical characteristics built-in. The relay optical system unit 43 has relay lens systems 22a, 22b, 22c and 22d of the same formation built-in. The adapter optical system unit 45 has a common adapter optical system 32 built-in. The image taking device unit 45 has image taking devices 33a and 33b of uniform characteristics built-in.

Fig. 16A as seen from the side is as in Fig. 16B. The objective optical system unit 42 has a distal end side section of a light guide 18 and an illuminating lens 20 built-in. The relay optical system unit 43 has an intermediate section of the light guide 18 built-in. The adapter optical system unit 44 has a rear end side section of the light guide 18 built-in. A light guide mouthpiece 13 is provided.

Also, in this embodiment, the relay lens systems 22a, 22b, 22c and 22d within the relay optical unit 43, for example, (for example, are cut off in the

lengthwise direction on the lower side to be in the direction vertical to the horizontal direction in which the objective optical systems 21a and 21b are arranged to secure a space to contain the light guide 18 and) make the inserted section small in the diameter. Also, the adapter optical system 32 within the adapter optical system unit 44 is cut off on the light guide mouthpiece 13 side.

In this embodiment, the objective optical system unit 42 is connected to the distal end of the relay optical system unit 43, the distal end of the adapter optical system unit 44 is connected to the proximal end of the relay optical system unit 43 and the image taking device unit 45 is connected to the proximal end of this adapter optical system unit 44 to form a stereoendoscope 41.

Therefore, by combining the respective units different in the optical characteristics and image taking characteristic, stereoendoscopes of different characteristics can be simply realized. Therefore, the stereoendoscopes 41 of different characteristics can be provided so as to be selected by the users for their using objects.

In this embodiment, the connecting part of the proximal end of the relay optical system unit 43 and the distal end of the adapter optical system unit 44 corresponds to the border of the input section 25 and output section 24 shown in Fig. 5.

By the way, in Figs. 16A and 16B, the part after the adapter optical system unit 44 is made large in

the diameter. However, as shown in Fig. 16C, the proximal end side of the relay optical system unit 43 may be made large in the diameter on the proximal end side, the proximal end side part of the light guide 18 may be built-in near this proximal end and the light guide mouth piece 13 may be provided there in the structure.

In this first modification, the light guide 18 need not be built-in in the adapter optical unit 44 and therefore the structure will be simple.

In this modification, the image taking device unit 45 may be fitted directly to the relay optical system unit 43 without using the adapter optical system unit 44 in the structure. In such case, the formation of the second embodiment will be made. Further, in case one common image taking device is built-in as the image taking device unit 45, the formation of the first embodiment will be made.

This first modification is higher in the freedom of combination than the ninth embodiment and can simply realize stereoendoscopes 41 different in the characteristics. Also, as shown in Fig. 16D, when an ocular adapter 45' is connected to the proximal end of the relay optical system unit 43, a stereoendoscope by which stereo-inspection can be made with the naked eyes will be able to be formed.

The ocular adapter 45' shown in Fig. 16D is of a structure whereby the final images by the relay optical system unit 43 can be magnified and observed respectively through prisms and ocular lenses 45"a and 45"b fitted to an ocular window corresponding to the distance between

both eyes of the operator so that the left and right images by the objective optical systems 21a and 21b may be respectively stereo-inspected through the left and right ocular lenses 45"a and 45"b.

By the way, in this case, as the final images are inverted images, the ocular adapter 45' is provided with lenses 45'a and 45'b as means for making them upright to form upright images in front of the ocular lenses 45"a and 45"b. Instead of providing the lenses 45'a and 45'b, the two prisms for extending the distance between the optical axes may be made such prisms for inverting images as Porro prisms.

The ocular adapter for observation with the naked eyes may be connectable to the relay optical system unit 43 in Fig. 16A in the structure or may be connectable to the second to fourth modifications of the ninth embodiment shown in Figs. 17A to 17C explained in the following.

In the second modification shown in Fig. 17A, in Fig. 16A, the adapter optical system 32 and the image taking devices 33a and 33b are formed of an adapter optical system image taking unit 46 as one unit.

In the third modification shown in Fig. 17B, in Fig. 17A, further, the objective optical systems 21a and 21b and the relay optical system 22 are formed of an objective optical system relay optical system unit 47 as one unit. In the fourth modification shown in Fig. 17C, in Fig. 16A, the relay optical systems 22 and the adapter optical system 32 are formed of a relay optical system adapter optical system unit 48 as one unit.

Figs. 18A to 18E show more concrete formations of various units used in the ninth embodiment and its modifications.

Fig. 18A shows an objective optical system unit 42 of a visual field angle of 70 degrees. Fig. 18B shows an objective optical system unit 42 of a visual field angle of 40 degrees. When they are replaced and are connected to a relay optical system unit 43, any desired visual field angle will be obtained.

A male screw is formed at the proximal end of the jacket tube of the objective optical system unit 42 and can be removably connected by being screwed to a female screw at the distal end of the jacket tube of the relay optical system unit 43. A projection is provided at the proximal end of the jacket tube of the objective optical system unit 43 and can be contacted with a level difference surface made by cutting off the inner peripheral surface on the distal end side of the jacket tube of the relay optical system unit 43 to determine the position in the lengthwise direction. By the way, both jacket tubes are of the same outside diameter so that, in case they are connected with each other, no level difference will be made on the inserted section.

Also, a positioning mark and screw hole are provided as peripheral positioning means near the proximal end of the jacket tube of the objective optical system unit 42. When this mark is made to meet a positioning mark at the distal end of the jacket tube of the relay optical system unit 43, both screw holes will be able to be set to communicate with each other and will be able to

be fixed with a screw not illustrated.

By the way, the same connecting means or connecting mechanism as on the proximal end side of the jacket tube of the objective optical system unit 42 is provided on the proximal end side of the jacket tube of the relay optical system unit 43 and can be removably connected to the distal end of the jacket tube of the adapter optical system unit 44.

Fig. 18C shows an objective optical system unit 42 perspective in the visual field direction of 45 degrees. In Fig. 18C, by replacing the reflecting prism 40, the objective optical system unit 42 perspective in any visual field direction can be formed. By the way, Fig. 18D shows Fig. 18C as seen from the rear end side and a pair of objective optical systems 39a and 39b arranged on the left and right.

Fig. 18E shows an objective optical system 42 in which the parallax is reduced and the optical axes of two objective optical systems 21a and 21b are near to each other and the distance d' between the optical axes is $d' < d$. In the case of this formation, the function of obtaining a stereo-feel will reduce but, as the objective optical systems are arranged on the center axis side, a space for inserting them through other internal organs or the like will be able to be secured, therefore, for example, the cross-sectioned area of the light guide will be able to be made large, the illuminating light amount will be able to be increased and a bright image will be obtained.

By the way, when the image taking device unit

or the adapter optical system unit is replaced, as required, in response to the optical axis distance and visual field angle of the objective optical systems 21a and 21b, an optimum stereoendoscope conforming to the equivalent will be able to be provided.

Fig. 19A shows a formation of a relay optical system unit 43. The proximal end of this relay optical system 43 can be removably connected to the distal end of the adapter optical system unit 44. Also, the proximal end of this adapter optical system unit 44 can be removably connected to the image taking unit 45.

As shown, for example, in Fig. 19B, the relay optical system unit may be the relay optical system unit 43 in which the number of relaying times is made twice. Further, a relay optical system unit in which the number of relaying times is different depending on the inserted length inserted into the body cavity or the like can be also used.

Fig. 19C shows a formation of an objective optical system relay optical system unit 47 integrating an objective optical system and a relay optical system. Fig. 19D is a modification of Fig. 19C and shows a unit in which the number of relaying times of the relay optical system is made twice. Various numbers of relaying times of the relay optical system can be prepared. A different length of the inserted section can be selected as required.

In the following, the tenth to eighteenth embodiments are embodiments of the formation (b) in the above mentioned paragraph of the summary. Images having a

parallax with each other are taken into the plural front group optical systems of the objective optical systems arranged in the distal end section of the endoscope and plural images in one rear group optical system are formed in substantially coinciding positions. These substantially superimposed images are transmitted by a common rear group optical system and a common image transmitting system coinciding with this rear group optical system in the optical axis.

Fig. 20 shows an image taking optical system in the tenth embodiment.

An objective optical system 51 in which the object side opening part is separated into two parts, relay lens systems 52a, 52b and 52c, an adapter optical system 50 and image taking devices 53a and 53b are arranged in the order mentioned from the object side. The objective optical system 51 is formed of front group optical systems (abbreviated merely as front groups) 54a and 54b of the same formation which are parallel arranged as separated by the distance d ($= 4 \text{ mm}$) between the optical axes of each other and a rear group optical system (abbreviated merely as a rear group) 55 arranged to be of one same optical axis. Two images 56a and 56b having a parallax are formed in spatially substantially coinciding positions.

The images 56a and 56b form a relay optical system and are equimultiply relayed by (for example, three) relay lens systems 52a, 52b and 52c of the same formation arranged in series so as to be of the same optical axis with each other.

That is to say, by the relay lens system 52a, the images 56a and 56b form images 57a and 57b with equal sizes in substantially the same positions in the rear of this relay lens system 52a. By the relay lens system 52b, these images 57a and 57b form images 58a and 58b with equal sizes in substantially the same positions in the rear of this relay lens system 52b. By the relay lens system 52c, these images 58a and 58b form images 59a and 59b with equal sizes in substantially the same positions in the rear of this relay lens system 52c.

The rear group 55 of the objective optical system 51 and the optical axis of the relay lens systems 52a, 52b and 52c are on the same axis. This optical axis and the optical axis of the front groups 54a and 54b are eccentric respectively on the left and right.

The eccentricity can be selected in conformity with a desired size, that is, the size of the stereo-feel and is respectively $d/2$ ($= 2 \text{ mm}$) in this embodiment. An afocal beam may not be between the front groups 54a and 54b and the rear group 55. However, for making small, this part may be of an afocal beam. An image formed by the objective optical system had better be substantially superimposed.

For the picture angle of the ordinary relay system, the picture angle required by the endoscope is large. From the condition that, as described above, the front groups 54a and 54b had better be nearly afocal and from the condition that non-common parts had better be few, the front groups 54a and 54b had better be formed of two groups of a concave group and convex group from the

object side.

When the plural images having a parallax and transmitted by the relay optical system are substantially superimposed, the relay optical system will be able to be made small in the diameter. Therefore, the projected pupil of the objective optical system 51 may be made substantially infinite. Therefore, the front side focal position of the rear group 55 of the objective optical system 51 will be the pupil position. In order that the beam entering the front groups 54a and 54b from the object may be well transmitted to the rear group 55, it is preferable to coincide with the projected pupil of the front groups 54a and 54b. Concretely, it is preferable that the final surfaces of the front groups 54a and 54b are arranged on the image side rather than in the front side focal position of the rear group 55.

In this embodiment, the number of relaying times is three times but can be selected and set multiply to be usually one time to ten and several times depending on such specifications as the length and diameter of the inserted section of the endoscope and the brightness and the like of the optical system.

The magnitude of the parallax, that is, the center distance between the right and left incident pupils is determined by the optical axis distance d between the front groups 54a and 54b of the objective optical system 51 and is independent of the brightness of the optical system.

According to this embodiment, the same as in the first embodiment, the two images 56a and 56b having a

parallax are transmitted by one axially symmetrical relay optical system and therefore an error will be little generated in the qualities (the magnification, MTF, image position, chromatic aberration, coloring and the like) of the two images being transmitted.

Non-common parts are less on the right and left of the objective optical system 51 than in the first embodiment. Therefore, the trouble of adjusting the lenses can be extremely omitted and a favorable stereo-observed image can be obtained.

Further, in this embodiment, as spatially substantially superimposed images are transmitted by the relay optical system, when each of the front groups 54a and 54b is formed of an elliptic lens system in which, for example, the horizontal direction is a short axis and the vertical direction is a long axis and the pupil is also made elliptic, the objective optical system and relay optical system will be able to be made small in the diameter without deteriorating the parallax, brightness and the like. In this case, the inserted section will be able to be made small in the diameter from the distal end to the proximal end side and the applied range in which the endoscope can be inserted and used will be able to be expanded. As the hole through which the inserted section is inserted into the abdominal part may be small, the pain given to the patient will be able to be reduced. By the way, even in the other embodiments, the objective optical system may be formed of an elliptic lens system.

In this embodiment, the final images 59a and 59b of the relay lens system 52c are in substantially the

same position and therefore must be separated from each other by any means which is a pupil dividing image forming means.

Therefor are required a means for forming an image of a pupil transmitted by the relay optical system and a means for forming an image of a partial beam of this pupil and forming an image by spatially separating plural images having a parallax. Concretely, performing it is the adapter optical system 50 formed of the pupil image forming lens system 61, mirror parts 62a and 62b and image forming lens systems 63a and 63b arranged to be on the same optical axis as of the relay lens system 52c.

The pupil image forming lens system 61 forms in spatially separated positions images of two pupils of the objective optical system 51 transmitted by the relay lens systems 52a, 52b and 52c. In the mirror parts 62a and 62b, the beams of the two pupils are parallel moved outside (in this embodiment, the movement is 6 mm) and the image forming lens systems 63a and 63b have an action of forming images 64a and 64b respectively in the image taking devices 53a and 53b.

The optical axes of the image forming lens systems 63a and 63b are eccentric by $d/2$ ($= 2 \text{ mm}$) from the optical axis of the relay lens system 52c except the parallel moved part by the mirror parts 62a and 62b. By the way, the mirror parts 62a and 62b and image forming lens systems 63a and 63b are illustrated respectively only on one side.

Lest the right and left pupils should be finally superimposed, a brightness diaphragm 79 may be

provided on the pupil surface (in this embodiment, on the projecting pupil surface of the pupil image forming lens) in any of the pupil position and its conjugate position to limit the beam.

In this embodiment, when the parallel moving distance in the mirror parts 62a and 62b and the magnification of the adapter optical system 50 are properly set, the images 64a and 64b optimum to the image taking devices 53a and 53b of any size will be able to be obtained.

As in Fig. 20, the parallel moving direction of the mirror parts 62a and 62b may be any direction within or vertical to the paper surface. When the focal distances of the image forming lens systems 63a and 63b are varied, the magnification will be able to be also varied.

In order to obtain the stereo-feel optimum to the operator's desire or a system, the optical axis distances between each other of the two front groups 54a and 54b may be made variable so that the magnitude of the parallax may be variable. In this case, in order to make the distal end section small, the two front groups 54a and 54b may be made movable in the directions reverse to each other vertically to the optical axis of the relay optical system.

However, in this case, as the projected pupil of the objective optical system is moved by the movement of the front groups 54a and 54b, it will be necessary to make the effective diameter of each lens rather large so that the beam may not be intercepted by the optical

systems following the relay lens systems 52a, 52b and 52c.

The others have the same operations and effects as of the first embodiment. The lens data of this embodiment are as in Table 6.

The following eleventh to seventeenth embodiments are of the formations made by modifying the tenth embodiment. The images having a parallax between each other are formed in spatially substantially coinciding positions. All these objective optical systems 51 can be formed to be interchangeable with the objective lenses of the pupil dividing type stereoendoscope of the related art.

Fig. 21 shows an image taking optical system in the eleventh embodiment of the present invention. Images 64a and 64b are formed by further once relaying the final images 59a and 59b of the relay lens system with the adapter optical system 50 and are taken by the image taking devices 53a and 53b.

The adapter optical system 50 is formed of a pupil image forming lens system 61 and image forming lens systems 63a and 63b arranged to be of the same optical axis as of the relay lens system 52c. The optical axes of the image forming lens systems 63a and 63b are eccentric by $1.25d$ ($= 5 \text{ mm}$) from the optical axis of the relay lens system 22c.

By the way, the image forming lens system is illustrated only on one side. This embodiment is simpler by the part having no mirror part within the adapter optical system 50 than the tenth embodiment. The same as in the tenth embodiment, when the magnification of the

adapter optical system 50 is freely set, the images 64a and 64b optimum to any image taking device will be able to be obtained. The distance between the two pupils divided by the pupil image forming lens system 61 can be varied by adjusting the focal distance of this pupil image forming lens system 61. The others have the same operations and effects as of the tenth embodiment.

The lens data of this embodiment are as in Table 7.

Fig. 22 shows an image taking optical system in the twelfth embodiment of the present invention. The front groups 54a and 54b of the objective optical system 51 are formed of meniscus lenses 65a and 65b having a concave surface on the object side. In this embodiment, as the non-common part of the right and left light paths is further less than in the eleventh embodiment, the error will be less between the qualities of the two images.

The lens data of this embodiment are as in Table 8.

Further, when the meniscus lenses 65a and 65b are made an integrally molded lens 65 as shown in Figs. 23A to 23D, the error on the right and left from the objective optical system 51 to the pupil image forming lens system 61 will be able to be reduced to a level where the error will not be a practical problem and the trouble of adjusting the lenses will be well eliminated. The others have the same operations and effects as of the eleventh embodiment.

By the way, of Figs. 23A to 23D, Fig. 23A is a sectioned plan view, Fig. 23B is a side view of Fig. 23A

as seen in the side direction and Figs. 23C and 23D are a front view and back view respectively as seen from the front side and back side.

Fig. 24 shows an image taking optical system in the thirteenth embodiment of the present invention. The final images 59a and 59b of the relay lens system are further once relayed by the adapter optical system 50. As the adapter optical system 50 is of the same optical axis as of the relay lens system 52c, the relayed images 64a and 64b will be formed in substantially the same positions and will be taken by one common image taking device 53.

A shutter 66 is arranged between the pupil image forming lens system 61 and image forming lens system 63 and alternately intercept the beam so that two images may not be simultaneously formed in the image taking device 53.

This embodiment has an advantage that one image taking device 53 will do. The others have the same effects as of the twelfth embodiment. The lens data of this embodiment are as in Table 9.

Fig. 25 shows a main part of an image taking optical system in the fourteenth embodiment of the present invention. The same as in the thirteenth embodiment, as the adapter optical system 50 is of the same optical axis as of the relay lens system 52c, the relayed images 64a and 64b will be formed in substantially the same positions and will be taken by one image taking device 53.

A lenticular lens 67 is arranged just before

the light receiving surface of this image taking device 53 which is to be used in common. When the right and left images are formed at intervals of one row or one line by the image taking device 53, the two images will be taken as separated. This embodiment has also an advantage that one image taking device 53 will do. The others have the same effects as of the thirteenth embodiment. By the way, the lens data of this embodiment are the same as of the thirteenth embodiment.

Figs. 26A and 26B show an objective optical system in the fifteenth embodiment of the present invention. In this embodiment, the visual field direction is 30 degrees with the lengthwise direction of the endoscope (the optical axis direction of the relay lens). The reflecting prisms 68a, 68b and 69a, 69b forming the front groups 54a and 54b may be respectively two separate bodies or one integral body.

Fig. 27 shows an objective optical system in a modification of the fifteenth embodiment of the present invention. The same as in the fifteenth embodiment, a perspective objective optical system 70 is formed. In this modification, the visual field direction is 70 degrees with the lengthwise direction of the endoscope (the optical axis direction of the relay lens). The reflecting prisms 68a, 68b and 69a, 69b may be respectively two separate bodies or one integral body.

In the fifteenth embodiment and its modification, the visual field direction can be varied by varying the angles of the reflecting prisms 68a, 68b and 69a, 69b. Therefore, when the front group part is formed

to be interchangeable, various visual field directions or visual field angles will be able to be obtained by interchanging only this front group. Needless to say, even when the entire objective optical system is formed to be interchangeable, the same effects will be obtained. The others have the same effects as in the tenth embodiment.

Fig. 28 shows an image taking optical system in the sixteenth embodiment of the present invention. The same as in the fifteenth embodiment, in this embodiment, the perspective objective optical system 70 is used. In this embodiment, the visual field direction is 45 degrees with the lengthwise direction of the endoscope (the optical axis direction of the relay lens). The reflecting prism 71 is integral on the right and left.

That is to say, in the illustrated tenth to fifteenth embodiments, the optical system divided into two parts of the front groups 54a and 54b is adopted. However, in this embodiment, a reflecting prism 71 as a common optical device is used to form a front group 54 functioning the same as the two separated front groups 54a and 54b.

Negative lens systems 72a and 72b as negative power elements and positive lens systems 73a and 73b as positive power elements to be a pair forming the front group 54 on the left and right are formed as arranged eccentrically respectively on the left and right and are rotatable as illustrated. Therefore, the arranging direction of the two incident pupils of the objective optical system, that is, the direction of the parallax

(the direction of d in Fig. 28) can be varied and it is very effective to stereo-observing an object in many directions.

In this embodiment, with the rotation of the negative lens systems 72a and 72b and positive lens systems 73a and 73b, the incident pupil of the pupil image forming lens system 61 will also rotate. In the embodiment shown in Fig. 28, the adapter optical system 50 shows an example in case the same formation as of the eleventh embodiment is adopted. The image forming lens systems 63a and 63b and the image taking devices 53a and 53b will rotate so as to be synchronized to prevent the beam from being intercepted.

Even in this embodiment, when the angle of the reflecting prism 71 is varied, the visual field direction will be able to be varied, when the combination of the focal distances of the negative lens and positive lens is varied, the visual field angle will be able to be varied and, when the optical axis distance between the negative lens and positive lens on the left and right is varied, the magnitude of the parallax will be able to be varied.

This embodiment can be applied to another adapter optical system. However, as mentioned above, with the rotation of the negative lens systems 72a and 72b and positive lens systems 73a and 73b, the projected pupil of the pupil image forming lens system 61 will also rotate. Therefore, it is necessary to rotate such parts having left and right separate optical axes as, for example, the mirror parts 62a and 62b, image forming lens systems 63a and 63b, image taking devices 53a and 53b and

the like as synchronized in the tenth embodiment in Fig. 20. The others have the same effects as of the tenth embodiment.

Fig. 29 shows the seventeenth embodiment of the present invention wherein the front group 54 including the negative lens systems 72a and 72b and positive lens systems 73a and 73b is arranged on the object side of the reflecting prism 71.

In this embodiment, as the rotating parts in the front group 54 part can be concentrated in one place (in this case, on the object side of the reflecting prism 71) as compared with the sixteenth embodiment, the formation is simple. Also, Fig. 29 shows an example wherein is used the adapter optical system 50 of the same formation as of the thirteenth embodiment. The opening part of the shutter 66 rotates as synchronized so that the beam may not be intercepted. At this time, such other parts as the image forming lens 63 and image taking device 53 may also rotate together with the shutter 66.

Fig. 30 shows unit formations of the eighteenth embodiment of the present invention. In Fig. 30A, the unit formation comprises the front group unit 81 having the front groups 54a and 54b built-in, the rear group - relay lens system - pupil image forming lens system unit 82 having the rear group 55, relay lens systems 52a, 52b and 52c and pupil image forming lens system 61 built-in, the image forming lens system unit 83 having the image forming lens systems 63a and 63b built-in and the image taking device unit 84 having the image taking devices 53a and 53b built-in. By the way, the connecting part of the

rear group - relay lens system - pupil image forming system unit 82 and the image forming lens system unit 83 corresponds to the border of the input section 25 and output section 24 shown in Fig. 5.

Fig. 30B shows a formation of the image forming lens system - image taking device unit 85 wherein, in Fig. 30A, the image forming lens systems 63a and 63b and image taking devices 53a and 53b are made one unit.

Fig. 30C shows a formation in Fig. 30A of the objective optical system unit 86 combining the front groups 54a and 54b in the front group unit 81 and the rear group 55 in the rear group - relay lens system - pupil image forming lens system unit 82, the relay lens system - pupil image forming lens system unit 87 having the relay lens systems 52a, 52b and 52c and pupil image forming lens system 61 built-in and the image forming lens system - image taking device unit 85 the same as in Fig. 30B.

In Fig. 30D, the objective optical system (that is, the front groups 54a and 54b and the rear group 55), relay lens systems 52a, 52b and 52c and pupil image forming lens system 61 are formed of the objective optical system - relay lens system - pupil image forming system unit 88 and the image forming lens system - image taking device unit 85 made one unit.

In Fig. 30E, the objective optical system and relay lens systems 52a, 52b and 52c are formed of the objective optical system - relay lens system unit 89 made one unit and the pupil image forming lens system 61, image forming lens systems 63a and 63b and image taking devices

53a and 53b are formed of the pupil image forming lens system - image forming lens system - image taking device unit 90 made one unit.

In Fig. 30F, the front group unit 81, rear group 55 and relay lens systems 52a, 52b and 52c are formed of the rear group - relay lens system unit 91 and pupil image forming lens system - image forming lens system - image taking device unit 90 made one unit.

In Fig. 30G, the relay lens systems 52a, 52b and 52c are formed of the relay lens system unit 92, objective optical system unit 86 and pupil image forming lens system - image forming lens system - image taking device unit 90 made one unit. By the way, in Figs. 30B to 30G, the lens system within each unit is shown with the reference numeral omitted.

Also, in Figs. 30A to 30G, the ocular adapter 45' shown in Fig. 16D may be made connectable.

In Fig. 31, the front group unit 81 is more concretely explained. Fig. 31A shows a front group unit 81 using a common front group 54. In case it is fitted, a pupil dividing type stereoendoscope in the related art will be able to be formed.

Fig. 31B shows the front group unit 81 of a visual field angle of 70 degrees. Fig. 31C shows the front group unit 81 of a visual field angle of 40 degrees. When they are replaced, any desired visual field angle will be obtained.

Figs. 31D and 31E show a front group perspective unit 81 of a visual field direction of 70 degrees. Fig. 31E is a view as seen from the rear of Fig.

31D. When the reflecting prism 71 is replaced, the front group perspective unit 81 of any visual field direction will be able to be formed.

Fig. 31F shows the front group unit 81 in which the parallax is reduced and the optical axes of the front groups 54a and 54b are neared to each other to make the distance d' smaller than the other optical axis distance d . In Figs. 31A to 31F, if the beams from the front groups 54a and 54b are made substantially afocal beams, when the unit is displaced, a focus lag and image lag will be able to be controlled.

Fig. 32 shows a formation of the objective optical system unit.

Fig. 32A shows an objective optical system unit 86 comprising the front group 54 and rear group 55 arranged to be of the same optical axis. When it is used, the pupil dividing type stereoendoscope in the related art will be able to be formed. Fig. 32B shows an objective optical system unit 86 having the front groups 54a and 54b of a visual field angle of 70 degrees. Fig. 32C is of an objective optical system unit 86 having the front groups 54a and 54b of a visual field angle of 40 degrees. When these are replaced, any desired visual field angle will be obtained.

Fig. 32D is of a perspective objective optical system unit 86 of a visual field direction of 70 degrees. Fig. 32E is a front view of Fig. 32D. When the reflecting prism 71 is replaced, a perspective objective optical system unit of any visual field direction will be able to be formed. By the way, in Fig. 32E, the light guide is

omitted.

Fig. 32F is of an objective optical system unit in which the parallax is reduced and the optical axes of the two front groups 54a and 54b are neared to each other so that the optical axis distance d' may be smaller than d , for example, in Fig. 32B and others.

Fig. 33 shows a formation of a unit including the rear group 55, relay lens systems 52a and 52b and pupil image forming lens system 61.

Fig. 33A is of the rear group - relay lens system - pupil image forming lens system unit 82 including the rear group 55, relay lens systems 52a and 52b and pupil image forming lens system 61. Fig. 33B is of the relay lens system - pupil image forming lens system unit 87 including the relay lens systems 52a and 52b and pupil image forming lens system 61. Fig. 33C is of the rear group - relay lens system unit 91 including the rear group 55 and relay lens systems 52a and 52b. Fig. 33 is of the relay lens system unit 92 comprising the relay lens systems 52a and 52b.

Any number of relaying times of the relay lens system can be used. As required, the inserted section different in the length can be selected.

The respective units in this eighteenth embodiment can be formed by adopting a part of the optical system of the tenth to seventeenth embodiment.

According to this eighteenth embodiment, the stereoendoscope of the formation adapted to the using object can be selected and used. The others have the effects of the tenth to seventeenth embodiments.

The following nineteenth and twentieth embodiments are embodiments wherein are used formations (a) in the means and operations for solving the above mentioned problems. When plural images taken in by an objective optical system and having a parallax between each other are transmitted by a common image transmitting optical system, are taken and are selectively displayed by a displaying means, the stereo-images optimum to the observers will be provided.

Fig. 34A shows a formation of a stereoendoscope apparatus 101 provided with the nineteenth embodiment of the present invention and an operation made by using the stereoendoscope 102 of the nineteenth embodiment. Fig. 34B shows an arrangement of an objective optical system 121 as seen from the distal end surface of the stereoendoscope 102.

This stereoendoscope apparatus 101 comprises a stereoendoscope 102 having an image taking means for taking plural images having a parallax built-in, a CCU 103 processing signals for this imaging means, a distributor 104 connected to this CCU 103 and distributing video signals, a color monitor 105 as plural displaying means displaying the video signals distributed by this distributor 104 and head mounted displays (abbreviated as HMD's) 106 and 107.

In Fig. 34A, a rigid inserted section 111 of the stereoendoscope 102 is inserted toward an affected part 114 from a hole 113 in an abdominal part 112 of a patient. Two operators 115 and 116 respectively fit HMD's to their head parts, observe the affected part 114 with

stereo-inspection and treat the affected part 114 by using treating tools 117 and 118. The treating tools 117 and 118 may be inserted through other holes or through channels in the stereoendoscope 102.

Also, another observer 119 (an assistant, nurse or spectator) observes the same affected part with stereo-inspection by observing the color monitor 105 with shutter spectacles 120 fitted.

The stereoendoscope 102 comprises an objective optical system 121, relay optical system 122, adapter optical system 123 and image taking means 124 in the order mentioned from the object side.

At least three images having a parallax between each other and formed by the objective optical system 121 are transmitted by one (or plural) relay optical system 122 and are spatially (or timely) separated and formed by respective image taking devices forming the image taking means 124. The electric signals of the respective images photoelectrically converted by the image taking means 124 are converted to video signals by the CCU 103, are further divided into signals of any two images by the distributor 104 and are displayed by the color monitor 105 and HMD's 106 and 107 which are to be displaying means.

In this embodiment, when the so far shown various optical systems are used as combined with the objective optical system 121 and adapter optical system 123, the stereo-image optimum to the respective operators and observers will be able to be provided very effectively.

When plural images are transmitted by one relay optical system built-in in one tubular inserted section 111, one hole 113 in the abdominal part 112 will do and the burden on the patient will be able to be reduced.

As shown, for example, in Fig. 34B, the objective optical system 121 is formed of six objective lens systems 121a to 121d arranged in the positions separated by a fixed distance from the center axis at an angle of 60 degrees from the center axis of the inserted section. The six images by these objective lens systems 121a to 121f are taken, for example, by six image taking devices forming the image taking means 124 through the common relay optical system 122 and the adapter optical system 123 formed, for example, of three adapter lens systems.

According to this formation, by selecting the image, for example, by the objective lens systems 121a and 121d, a stereo-image large in the parallax can be obtained and, by selecting the image by the objective lens systems 121b and 121e, a stereo-inspection large in the parallax in the direction different by 60 degrees is possible. Further, by selecting the image by the objective lens systems 121c and 121f, a stereo-inspection large in the parallax in the direction different by 120 degrees is possible.

Further, by the combination in the above mentioned case, the parallax will become small. However, by selecting the image, for example, by the objective lens systems 121a and 121c or the objective lens systems 121a and 121e, an image having a stereo-feel in various

directions can be obtained.

By the way, a remote display selecting means whereby the operator 115 using the displaying device can remotely select the two images distributed by the distributor 104 to the displaying device side of the HMD 106 or the like by a wireless remote controlling apparatus using infrared rays or ultrasonic waves may be provided.

An observing direction displaying means whereby, in case the image by the objective lens systems (for example, 121b and 121e) in the parallax direction different from the parallax direction of a set of objective lens systems (for example, 121a and 121d) as a reference is selected, the parallax direction changing angle (in this case, 60 degrees) will be displayed within the displaying device so that the direction in which the operator 115 or the like is observing may be simply found may be provided.

By the way, in this embodiment, n (at least three or plural) (in Fig. 34, $n = 6$) objective images are transmitted by one relay optical system 122 but may be transmitted by $n-i$ relay optical systems (here, $i = 1$ to $n-1$).

Fig. 35 shows a formation of the stereoendoscope 131 of the twentieth embodiment of the present invention. Fig. 35A shows a general formation of the stereoendoscope 131. Fig. 35B shows an elevation as seen from the distal end surface in Fig. 35A. Fig. 35C shows an arrangement of image taking devices as seen from the front surface side in Fig. 35A. In this embodiment, too,

plural sets of stereo-images can be obtained.

Plural front groups 133 (133a to 133f) forming an objective optical system 132 arranged on the distal end side of the rigid inserted section 111 take in images having a parallax between each other and an image 135 is formed in substantially superimposed positions by one rear group 134 to be common, is relayed some times by one relay optical system to be common and becomes a final image 137.

This final image 137 is of plural images as superimposed. These images have their pupils spatially separated by a pupil image forming lens system 138 and, further, respective images 141 (141a to 141f) are formed on CCD's 140 (140a to 140f) by image forming lenses 139.

In this embodiment, six images having a parallax between each other can be obtained. When two of them are selected and displayed, the images having various stereo-feels and parallaxes will be able to be stereo-inspected. Also, plural persons can stereo-observe in separate directions.

Figs. 36A to 36F show distal end side formations of the stereoendoscope of the twenty-first embodiment of the present invention. Fig. 36B is an elevation of Fig. 36A. Fig. 36C shows an optical system as seen from the side of Fig. 36A. Fig. 36D is an elevation of Fig. 36C. Fig. 36E shows Fig. 36C as bent. Fig. 36F is an elevation of Fig. 36E.

In this embodiment, the inserted section 152 can be bent on the distal end side.

A front group optical system 153, a rear group

154a forming a relay optical system 154 and a relay lens system 154b are arranged from the distal end side within the inserted section 152. The distal end section 155 of the inserted section covering the objective optical system 153 is formed of a tubular frame having a curvable hose structure. The proximal side from the relay optical system 154 is formed of a rigid tubular frame.

Mirrors 158 and 159 are arranged between concave lenses 156a and 156b as of a front group and convex lenses 157a and 157b forming the objective optical system 153 and are rotatable respectively around axes 161 and 162.

When the mirrors 158 and 159 are rotated simultaneously with curving from the straight seen state in Fig. 36C, the distal end section 155 will be curved to be bent as in Figs. 36E and 36F. According to this embodiment, the observation can be made with the distal end section bent. The others have the same effects as of the first embodiment and others.

Fig. 37 shows a formation on the distal end side of the stereoendoscope of the twenty-second embodiment of the present invention. This embodiment is a combination of the twentieth embodiment wherein plural sets of stereo-images can be obtained and the twenty-first embodiment having a bendable structure.

Usually, in an endoscope operation, the endoscope is not pierced directly into the abdominal part but is inserted through a tragacanth 171. The thinner this tragacanth 171, the less the burden on the patient. On the other hand, in case plural operators jointly

operate, it will be convenient that the observation can be made respectively in the separate directions.

However, there is a limit to enlarging the parallax and the parallax can not be made larger than the outside diameter of the distal end section. This embodiment can cope with such circumstances and makes it possible to observe in separate directions.

In this embodiment, two bendable distal end sections 155 and 155' are provided forward of the relay optical system 154 and objective optical systems 153 and 153' of the same structure as in the twentieth embodiment in Fig. 36 are contained within the respective distal end sections 155 and 155'. The same members as in Fig. 36 within the distal end section 155 shall bear the same reference numerals, the same members as in Fig. 36 within the other distal end section 155' shall bear the same reference numerals fitted with ' and their explanation shall be omitted.

According to this embodiment, when the distal end section is inserted within the tragacanth 171, it will be seen as straight as in Fig. 36C. When the distal end section comes out of the tragacanth 171, it will be bent as in Fig. 37A and plural observers will be able to observe in separate directions through one thin relay optical system 154.

By the way, for example, in the first embodiment, each of the objective optical systems 21a and 21b may be formed of an anamorphic optical system wherein the image forming magnification in the horizontal direction can be made smaller than the image forming

magnification in the vertical direction (intersecting at right angles with this horizontal direction).

In the case of this formation, particularly, in case a common image taking device 23 is adopted, the two right and left images will be able to be prevented from being superimposed and the right and left image taking ranges in the image taking device 23 will be able to be substantially expanded.

In the function of transmitting images by the relay optical system 22, as the right and left images can be less intercepted (than in the case of no anamorphic optical system), that much, the objective optical systems 21a and 21b will be able to be arranged as more separated from each other (with the optical axis distance d larger) and a picture image having a higher stereo-feel will be able to be obtained.

In this case, in the CCU 4, the signal of extending the picture image in the horizontal direction or compressing the picture image in the vertical direction may be processed.

By the way, the relay optical system 22 may be also formed of an anamorphic optical system. Even in the other embodiments, the objective optical system, relay optical system and adapter optical system may be formed of anamorphic optical systems.

By the way, in the lens data of the respective embodiments, in case the same lenses are paired in the objective optical system, adapter optical system and the like, only the lens data of one of the pair will be shown. In the respective embodiments, the relay lens optical

system formed of a homogeneous bar-like lens is shown. However, even in case a refractive index distributing type lens is formed of such non-homogeneous rod as of a Shelphock (trade name) and is used for the relay optical system (image transmitting optical system), the present invention will be effective.

By the way, the embodiment wherein plural images having a parallax are formed in spatially separated positions by the objective optical system and the embodiment wherein plural images having a parallax are formed in spatially substantially coinciding positions have been explained. However, the case of their intermediate functions, that is, the case that plural images having a parallax are formed in spatially at least partly superimposed positions and the case that plural images having a parallax are formed in spatially at least partly separated positions belong to the present invention. Also, the case of applying an image by an objective optical system to the case that the image by the objective optical system is transmitted by such image transmitting optical system as the relay optical system belongs to the present invention.

As explained above, as the stereoendoscope in the first to twenty-second embodiments is provided with an objective optical system having plural incident pupils formed in different positions and forming plural images having a parallax between each other having passed through these plural incident pupils and a common image transmitting optical system transmitting the plural images having a parallax between each other, the parallax

will be able to be made large by the optical system, a sufficient stereo-feel will be obtained, the parts of the light path transmitting plural images will be able to be made common by making the image transmitting optical system common, the number of the parts will be able to be reduced and the dispersion of plural images by production errors will be able to be extremely prevented.

When a stereoendoscope is formed by providing plural objective optical systems arranged in parallel, separating plural images having a parallax and forming images and a common image transmitting optical system transmitting the plural images, the parallax will be able to be made large by the optical system, a sufficient stereo-feel will be obtained, the parts of the light path transmitting plural images will be able to be made common by making the image transmitting optical system common, the number of the parts will be able to be reduced and the dispersion of plural images by production errors will be able to be extremely prevented. Further, as the images transmitted by the image transmitting optical system are spatially separated, the stereo-inspection will be made possible by the image taking means and ocular optical system without using an image separating means.

Also, when a stereoendoscope is formed by providing plural front group optical systems, common rear group optical systems forming objective optical systems forming plural images having a parallax in spatially substantially coinciding positions and a common image transmitting optical system transmitting the plural images, the parallax will be able to be made large by the

optical system, a sufficient stereo-feel will be obtained, the parts of the light path transmitting plural images will be able to be made common by making the image transmitting optical system common, the number of the parts will be able to be reduced and the dispersion of plural images by production errors will be able to be extremely prevented. When a common rear group optical system is used in the objective optical system part, many parts will be able to be made common and plural picture images less influenced by production errors and high in the quality will be obtained.

Further, there is a stereo-inspectable endoscope in U.S. patent No.5191203 shown in Fig. 38A wherein an objective optical system 500 is formed of collimator lenses 501 and a pair of left and right image forming lenses 502a and 502b arranged in the order mentioned from the object side.

In the objective optical system of the stereoendoscope of this related art, there are the following three problems:

(1) When the picture angle is to be made large, the inward angle will not be able to be made large and the stereo-feel will reduce.

As in Fig. 38B, in case the picture angle is to be made large, it will be necessary that the power arrangement of the collimator lenses 501 will be negative and positive in the order from the object side. When the power of the negative lens 503 on the object side is made large, the picture angle will be able to be made large. However, in this case, the focal distance f_c of the

collimator lenses 501 will become larger than the object distance s and the inward angle α will become small by the following formula:

$$\alpha = 2 \cdot \arctan (d/2 fc)$$

wherein d represents an optical axis distance between the two image forming lenses 502a and 502b.

(2) A relative error between the left and right images is likely to occur.

The relative error between the right and left images is produced mostly in the parts of the left and right separate bodies by a surface shape error, surface distance error, eccentricity error or the like between right and left independent lens systems. In the prior example, the parts of the left and right separate bodies (the parts having left and right separate optical axes) correspond to the image forming lenses 502a and 502b which are so many that an error is likely to occur. When a relative lag (focusing, eccentricity or the like) is produced between the left and right images, the left and right images will become hard to resolve and fatigue will be caused.

(3) It is difficult to adjust the eccentricity error of the left and right images.

In order to adjust the eccentricity error of the left and right images, the lens or CCD of the left and right separate body parts are adjusted. However, in the prior example, either is in a position through the other part (in this case, the collimator lens 501) from the distal end section of the endoscope and is difficult to adjust.

The twenty-third to twenty-fifth embodiments intended to provide a stereoendoscope wherein the picture angle and stereo-feel (inward angle) can be set to be optimum, the error between the left and right images is small and is easy to adjust and the fatigue is little for these three problems shall be explained.

In the stereoendoscope of these embodiments, there are an elongate inserted section, an objective optical system arranged within the distal end of the inserted section and an image taking means arranged within the inserted section and taking object images formed by the objective optical system, the objective optical system is formed of two negative lenses and one coaxial positive lens arranged in parallel with each other in the order mentioned from the object side, the inward angle is determined by the optical axis distance between the two negative lenses, therefore the picture angle and stereo-feel (inward angle) can be set to be optimum, the error between the left and right images is small and is easy to adjust and the fatigue feel can be reduced. in the stereoendoscope having an elongate inserted section,

In the twenty-third embodiment, the objective optical system is applied to a so-called electronic scope having a CCD in the distal end part of the inserted section of the endoscope.

As shown in Fig. 39, a stereoendoscope apparatus 201 comprises a stereoendoscope 202 of the twenty-third embodiment having an image taking optical system for stereo-inspection built-in, a light source apparatus 203 feeding an illuminating light to an illuminating light

transmitting means transmitting the illuminating light and provided in this stereoendoscope 202, a camera controlling unit (abbreviated as CCU hereinafter) processing signals for an image taking means built-in in this stereoendoscope 202, a scan converter 205 converting to a video signal the signal put out of this CCU 204, a color monitor 206 displaying the video signal put out of this scan converter 205 and shutter spectacles 207 having a shutter function of stereo-perceiving the picture image displayed by this color monitor 206.

The stereoendoscope 202 has an elongate inserted section 208 to be inserted into a body cavity or the like and a gripped section 209 to be gripped by the operator and formed to be thick at the proximal end of this inserted section. This inserted section 208 is formed of a cylindrical metallic hose high in the flexibility and a soft jacket tube made of a metallic mesh and resin or the like. The distal end section 216 of the inserted section 208 is formed of a cylindrical rigid jacket tube made of such metal as stainless steel. An objective optical system 218 and two image taking devices 220a and 220b (for example, CCD's) are enclosed in the distal end section 216. By the way, the entire inserted section may be formed of a rigid jacket tube the same as in the distal end section.

This stereoendoscope has a light guide 215 as an illuminating light transmitting means transmitting the illuminating light fed from the light source apparatus 203 and an illuminating optical system (not illustrated) emitting the transmitted illuminating light through an

illuminating window the same as in the ordinary endoscope, obtains two observed images having a parallax so that the object illuminated by this illuminating optical system may be stereo-inspected and has an observing optical system comprising the optical system 218 and two image taking devices 220a and 220b.

By the way, this embodiment explains an example wherein two images having a parallax are formed by the image taking devices 220a and 220b having a photoelectrically converting function as an observing optical system and is therefore called also an image taking optical system.

The gripped section 209 is provided with a light guide mouthpiece 210 to which a light guide cable 211 is removably connected at one end. A light guide connector 212 at the other end of the light guide cable 211 is removably connected to the light source apparatus 203.

A lamp 213 generating a white illuminating light and a lens 214 condensing this white light are arranged within the light source apparatus 203. The illuminating light condensed by this lens 214 is radiated on the end surface of the light guide connector 212, is transmitted by the light guide within the light guide cable 211, is transmitted from the light guide mouthpiece 210 to the light guide 215 side within the stereoendoscope 202 and is fed.

The light guide 215 as an illuminating light transmitting means is bent within the gripped section 209 and is inserted through the inserted section 208. This

light guide 215 transmits the fed illuminating light and emits the illuminating light forward from the distal end surface fixed to the distal end section 216 of the inserted section 216.

An object (indicated by the arrow in Fig. 39) 217 illuminated by this illuminating light has optical images (219a and 219b in Fig. 39) having a parallax between each other formed in image forming positions by the objective optical system 218 fitted to an observing window arranged adjacently to the illuminating window within the distal end section. These images 219a and 219b are formed on the photoelectric converting surfaces (image taking surfaces) of the image taking devices 220a and 220b arranged the same within the distal end of the inserted section.

As shown in Fig. 40, the objective optical system 218 is formed of left and right separate negative lenses 221a and 221b and an axially symmetrical positive lens group 222 arranged in parallel with each other in the order mentioned from the object side. The light having passed through a diaphragm opening 223b of the light from the object forms an image on the image taking device 220a and the light having passed through a diaphragm opening 223a forms an image on the image taking device 220b. By the way, a cover glass 240 made of parallel plane plates is arranged on the object side of the negative lenses 221a and 221b.

Here, the lens data of the objective optical system 218 of this embodiment are shown in Table 10.

In Fig. 39, the image taking devices 220a and

220b have, for example, square image taking surfaces. The vertical or horizontal direction of this image taking surface coincides with the horizontal direction in which the two diaphragm openings 223a and 223b are separated and arranged.

The image taking devices 220a and 220b are extended out and are connected with the CCU 204 by the signal cable 224. The image taking signal photoelectrically converted by the image taking devices 220a and 220b is processed in the CCU 204. The image signal processed in this CCU 4 is further put into a scan converter 205 and is converted to a video signal. The video signal is put out in a color monitor 206 in which the picture images having a parallax between each other and separately formed through the two diaphragm openings 223a and 223b are alternately displayed and the operator can observe and stereo-inspect the picture images with the shutter spectacles.

Fig. 41 shows a power arrangement of the objective optical system 218 in this embodiment. The inward angle α determining the magnitude of the stereo-feel is as follows from the optical axis distance d between the two negative lenses 221a and 221b and the object distance s :

$$\tan (\alpha / 2) = d / (2 s) .$$

That is to say, as shown in Fig. 41, the inward angle of the objective optical system in this embodiment is determined by the optical axis distance d between the two negative lenses and does not depend on the picture angle. Further, as the left and right separate parts are

only the negative lenses 221a and 221b, no relative error will be likely to be produced. Therefore, there can be obtained the effects that:

(1) As the inward angle is determined by the optical axis distance between the two negative lenses and the inward angle and picture angle can be independently set, the picture angle will be able to made large with the inward angle kept large.

(2) As the main cause of the relative error between the left and right images is only the negative lens, the relative error between the left and right images will be little.

(3) As the left and right separate parts for adjusting the error between the left and right images are on the distal end side of the endoscope, they will be easy to adjust.

Fig. 42 shows a frame structure of the distal end section 216 of the stereoendoscope 202 in this embodiment. The frame structure comprises an inner tube 225 holding lenses and a CCD and an outer tube 226 enclosing the inner tube 225, an illuminating light guide and forceps channel not illustrated.

In the objective optical system of the prior example in Fig. 38A, as the left and right separate bodies for adjusting the eccentricity of the left and right images are in the positions through the collimator lens from the distal end within the inner tube, when they are to be adjusted, adjusting grooves, screws and adjusting spaces will have to be prepared in the inner tube and the inner tube will not be able to be made the

inner tube 25 of such simple structure as in Fig. 42 and will be large in the outside diameter.

On the other hand, in this embodiment, as the two negative lenses 221a and 221b which are the left and right separate parts to be adjusted are outside the distal end of the inner tube 225, the positions of the negative lenses 221a and 221b will be able to be simply adjusted without making the inner tube 225 have a special structure. The negative lenses 221a and 221b are adjusted in the position and are then bonded and fixed and the inner tube 225 is inserted into the outer tube 226 to complete the stereoendoscope.

The twenty-fourth embodiment shall be explained in the following with reference to Fig. 43. As the twenty-fourth embodiment is substantially the same as the twenty-third embodiment, only the different formations shall be explained.

In the twenty-fourth embodiment, the objective optical system of the stereoendoscope according to the present invention is applied to a so-called rigid endoscope wherein an image is transmitted to the proximal side by an objective optical system 218 and transmitting optical system 227 arranged in an inserted section consisting of a cylindrical rigid jacket tube and is taken.

As shown in Fig. 43, images 219a and 219b formed by the objective optical system 218 are relayed by relay lenses 227a, 227b and 227c which are of a transmitting optical system 227 and are then formed on CCD's 229a and 229b by an image taking lens 228. All the

other lenses than the negative lenses 221a and 221b at the distal end are coaxial. The images, that is, pupils of the diaphragm openings 223a and 223b are transmitted respectively to positions 250, 251, 252 and 253. The other formations, operations and effects are the same as of the twenty-third embodiment.

Here, the lens data of the objective optical system 218 and transmitting optical system 227 in this embodiment are shown in Table 11..

The image taking lens 228 in this embodiment is one coaxial lens system but the two pupils are separated in the position 253. Therefore, as the image forming lens of the image taking lens shown in the following, image forming lenses arranged in parallel with each other may be used after the pupil 253 to form images.

The twenty-fifth embodiment shall be explained in the following with reference to Figs. 44 and 45. As this embodiment is substantially the same as the twenty-fourth embodiment, only the different formations shall be explained.

The twenty-fifth embodiment is an embodiment as applied to a rigid endoscope the same as the twenty-fourth embodiment.

In this embodiment, as shown in Fig. 44, the basic formation of the objective optical system 218 is the same as in the twenty-fourth embodiment. However, the image 219a formed of the light having passed through the diaphragm opening 223b of the light from the object and the image 219b formed of the light having passed through the diaphragm opening 223a are partly superimposed.

The images 219a and 219b formed by the objective optical system 218 are relayed by the relay lenses 227a and 227b as shown in Fig. 45, are then formed to be infinite by the pupil image forming lens 230 and are formed respectively on the CCD's 229a and 229b by a pair of left and right image forming lenses 231a and 231b. The images (pupils) of the diaphragm openings 223a and 223b are transmitted respectively to the positions 254, 255 and 256. As the two pupils have been separated in the position 256, the two partly superimposed images 233a and 233b relayed by the relay lenses 227a and 227b are formed as separated by the image forming lenses 231a and 231b. The other formations, operations and effects are the same as in the twenty-fourth embodiment.

Here, the lens data of the objective optical system 218 and transmitting optical system 227 of this embodiment are shown in Table 12.

In the 25th embodiment, the left and right separate parts are present not only in the distal end section (the negative lenses 221a and 221b) but also within the image taking lens 232 (the image forming lenses 231a and 231b). Therefore, when the negative lenses are not adjusted but the image forming lenses are adjusted, the eccentricity error between the left and right images will be able to be adjusted.

However, in case the stereoscope 202 is made removable between the input section (until the transmitting optical system 227 or until the pupil image forming lens) and the output section (after the pupil image forming lens 230 or after the image forming lenses

231a and 231b), it will be necessary that the input section and output section will be respectively independently adjusted. Therefore, even in such adjustment of the input section, the objective optical system of the present invention is very effective.

A plural visual field direction type endoscope after the 26th embodiment shall be explained in the following.

The endoscope apparatus 310 shown in Fig. 46 has an inserted section 302, an endoscope 311 in which the visual field direction is changeable in the 26th embodiment, a camera 304, monitor 305 and light source apparatus 307.

An objective optical system having plural visual field directions and a light guide illuminating the respective visual field directions are incorporated in the distal end section 301 of the inserted section 302 of the endoscope 311. The inserted section 302 is provided with a relay lens system which is an image and pupil transmitting optical system following the objective optical system. An ocular optical system is arranged in the proximal section 303 of the endoscope 311. The camera 304 can be fitted in the rear of the ocular optical system. Here, the proximal section 303 of the endoscope 311 and the camera 304 are formed to be integral or removable. The object having had the image taken by the camera 304 is displayed to be observable by the observer as an endoscope picture image finally in the monitor 305.

The illuminating light from the light source apparatus 307 passes through the light guide cable 306

and illuminates the respective visual field directions through the proximal section 303, inserted section 302 and distal end section 301.

The details of the optical system of the endoscope 311 shall be explained in the following:

On the optical systems of the endoscope of the 26th embodiment, a pupil division is utilized in the objective optical system and an ocular optical system is formed.

The pupil dividing system is fundamentally formed of an optical system having one optical axis but, in order to make a plural visual field direction type, a lens group corresponding to plural visual field directions is arranged in front of the optical system. The plural visual field direction type optical system having adopted this pupil dividing system is formed of a front side lens group formed the same in plural visual field directions and arranged in the respective visual field directions, a prism for forming images in the plural visual field directions in the rear step of the front side lens group corresponding to the plural visual field directions, a brightness diaphragm having plural openings arranged near pupils to make plural pupils and a rear side lens group forming one image of superimposed beams in the plural visual field directions in the order mentioned from the object side.

The inherent one beam of the optical system is divided near the pupil by the brightness diaphragm 321 having two openings and shown in Fig. 37B. The beam passing through one opening of the brightness diaphragm

321 is straight seen as it is and the beam passing through the other opening of the brightness diaphragm 321 is perspectively seen in the visual field direction by the prism. Here, the two images in the visual field direction are formed as superimposed on the image surface.

The formation of the optical system relating to this embodiment shall be explained concretely with reference to Fig. 47A. The optical system shown in Fig. 47A comprises an objective optical system 322, a set of relay lens system 323 as a transmitting optical system and an ocular optical system 324.

The objective optical system 322 has a front side lens group 329a comprising two objective lenses 325 and 326 arranged in the positions nearest to the object and directed respectively in the straight seen direction and side seen direction, a first prism 327 making the beam from the two objective lenses 325 and 326 incident on different surfaces, a second prism 328 making the beam from the first prism 327 incident on the same surface and a brightness diaphragm 321 for dividing the pupil into plural pupils in response to the visual field direction and has a rear side lens group 329b for converging the beam from the pupils and forming the object image arranged in the rear of this front side lens group 329a. In the drawing, the one-point chain lines represent the optical axes of the respective visual field directions.

The image in the straight seen direction in this optical system is formed as follows. The rays having passed through the straight seeing objective lens 326

pass through the surface 331 of the first prism 327 to the joint surface 332. The joint surface 332 on the first prism side 327 is black-painted so as to pass no others than the rays effective to prevent detrimental flares and is made a flare diaphragm. As the first and second prisms 327 and 328 are made of the same glass material, their refractive indices are equal and the rays pass through the surface 332 without being refracted, Then an image I1 having the lower side of the brightness diaphragm 321 as a pupil surface and having the optical axis of this rear side lens group 329b as a center axis by the rear side lens group 329b is formed.

On the other hand, the image in the perspectively seen direction is formed as follows. The rays having passed through the perspectively seeing objective lens 325 pass through the surface 333 of the first prism 327 to the joint surface 332. At this time, the rays forming the image in the perspectively seen direction proceed straight through the joint surface without being refracted the same as the straight seen rays.

The joint surface 332 on the first prism side 327 is made a flare diaphragm passing no others than the rays effective to prevent detrimental flares. As the optical axis in the straight seen direction and the optical axis in the perspectively seen direction intersect with each other on the joint surface, the same flare diaphragm will effectively function on the rays in both directions. The straight proceeding rays in the perspectively seen direction are reflected by the

mirror-processed surface 334 and go again to the surface 332 on the second prism 328 side.

The surface 332 on the second prism 328 side is mirror-processed in the range of not intercepting the straight seen rays and perspectively seen rays separated by the pupil division and in the range of covering the reflected perspectively seen rays reflected by the surface 334. Therefore, the rays in the perspectively seen direction reflected by the surface 334 without being perceived pass on the upper side of the brightness diaphragm 321 and are made the image I1 having the optical axis of the rear side lens group 329b as a center axis by this rear side lens group 329 the same as the straight seen rays and the image is formed.

The images I1 in the plural visual field directions made by the objective optical system 322 and the pupil P1 are transmitted in the ocular optical system direction by the relay lens system 323. In the drawing, the reference numeral P2 represents plural pupils corresponding to the respective visual field directions transmitted by the relay lens. An image I2 is formed between the relay lens system 323 and ocular optical system 324. Plural pupils P3 corresponding to the respective visual field directions are obtained through the ocular optical system 324.

When the observer moves the position of his pupil to the position of the pupil transmitted in the visual field direction he wants to observe, he will be able to select the visual field direction.

In this embodiment, the objective optical

system is originally designed as a coaxial optical system but not as an eccentric optical system and is formed to be bent with a prism for a pupil in a different visual field direction. That is to say, the optical axis of the objective lens 326 is on the extended line of the optical axis of the rear side lens group 329b through the joint surface 332 and the optical axis of the objective lens 325 is on the extended line of the optical axis of the rear side lens group 329b reflected on the joint surface 332 and further reflected on the reflecting surface 334.

Therefore, between the optical system comprising two negative lenses and a prism and the optical system in the rear of it, even if the beam is not afocal, two images superimposed before the relay system will be able to be formed.

In this embodiment, as the pupil division is utilized and originally one optical system is used, with a formation of few lenses, a high picture quality will be obtained, if the means for determining plural pupils is in a position conjugate with the pupil position of the objective optical system, it may be the position of the pupil P2 of the relay system 323 or any other part and, as the objective system and transmitting optical system have no visual field direction switching apparatus, the structure will be simple and the assemblability will be high.

An example of designing an actual objective optical system is shown in Fig. 48 and its numerical value data are mentioned in Table 13. By the way, in the formation shown in Fig.48, the part shown as the rear

side lens group 329b in Fig. 47A is formed of a lens 329" jointed to a prism and three jointed lenses 329'.

In this embodiment, as the formed image is one, the following effects will be able to be obtained.

That is to say, as the objective optical system of the plural visual field direction type endoscope has plural visual field directions, plural pupils corresponding at 1 to 1 to the visual field directions and one image, the one image is a superimposition of images in plural visual field directions, the optical axis of plural visual field directions coincides with the optical axis of the transmitting system in the position of the image and, on the way of the transmission in the transmitting optical system after the image, one image and plural pupils will be transmitted without being intercepted.

Therefore, in this embodiment, after the transmitting optical system, the visual field direction can be selected and no movable part is required in the objective optical system and transmitting optical system for selecting the visual field direction. Further, in this embodiment, as the objective optical system and the like have no visual field direction switching apparatus, the structure will be simple and the assemblability will be high. Also, as no polarization is used, there will be no deterioration of the image in the peripheral part by the rotation in the polarizing direction.

These effects will be the same even in case the pupil dividing means is in the transmitting optical system or image forming optical system.

The 27th embodiment shall be explained in the following with reference to Figs. 49 to 54.

In the endoscope of this embodiment, an eccentric optical system is utilized for the objective optical system, an image forming optical system and solid state image taking device are used instead of the ocular optical system in the 26th embodiment and no optical visual field direction selecting means is provided.

Fig. 49A shows a formation of an optical system arranged within the endoscope of this embodiment.

The optical system of this embodiment comprises in the order mentioned from the distal end side an objective optical system 341, relay lens system 342, pupil image forming lens 343, such reflecting members 344a and 344b as a pupil separating optical member 344c and mirror and two solid state image taking devices 346a and 346b as image taking means. By the way, though only one relay lens system is shown, it is natural that plural relay lens systems may be used as required. The image forming lenses 345a and 345b form the image forming optical system.

In the objective optical system 341, a front optical system 347 comprising substantially afocal lens groups 347a and 347b independent of each other and having two straight seen and perspectively seen visual field directions and pupils P11 corresponding to these visual field directions is arranged in the front group and a rear side lens system 348 having a size capable of transmitting the beams from the plural pupils P11 to the image without being intercepted and forming one

superimposed image of the beams in the plural visual field directions is arranged in the rear group.

The relay lens system 342 forms the images of the pupils P11 as pupils P12, forms the image I11 as an image I12 and transmits them to a pupil image forming lens 343. The pupil image forming lens 343 transmits the pupils transmitted from the relay lens system 342 to the side of a pupil separating optical member 344c having plural reflecting surfaces. This pupil separating optical member 344c receives plural pupils P13 and separates and delivers them in respectively different directions, that is, to the reflecting members 344a and 344b.

The reflecting members 344a and 344b reflect the beams having passed through the separated respective pupils, that is, in the illustration, the two pupils corresponding to the optical system in the straight seen direction and the optical system in the perspective seen direction respectively toward the lens systems 345a and 345b. The lens systems 345a and 345b form images corresponding to the respective pupils in the solid state image taking devices 346a and 346b.

In this formation, first the rays in the respective visual field directions pass through two substantially afocal lens groups 347a and 347b forming the front optical system 347, then the optical axes in the respective visual field directions are bent by the rear side lens system 348 and the image I11 is formed on the optical axis of the rear side lens system 348.

In this embodiment, substantially the same basic formation as realize the perspective view made by

the prisms 327 and 328 in the 26th embodiment is used. Here, the perspective view prism may be a 30° prism shown in the publications of Japanese Patent Applications Laid Open Nos.140313/1985, 91333/1975 and 108013/1990 or a 70° prism or 110° prism shown in the publication of Japanese Patent Application Laid Open No.87403/1984.

Also, the objective optical system 341 may be the front optical system 347c including the same prisms as the prisms 327 and 328 of the above mentioned embodiment as in Fig. 50, that is, may be a straight seeing and perspective seeing optical system in common. Or the objective optical system 341 may realize a perspective view by utilizing refraction with a wedge prism 349 placed near the pupil P11 as in Fig. 51. In this formation, the lens group to be used respectively in the straight seen direction and the perspective seen direction may be substantially the same lens group different only in the length, the perspective seeing lens group may be arranged as inclined to the straight seeing lens group and the wedge prism 349 may be arranged in the rear of it.

Or else, as shown in Fig. 54, the objective optical system 341 may have three or more visual field directions if in a range that the image and pupil are not intercepted by the relay lens system arranged in the rear. In the illustrated example are shown the most distal end side lenses 350, 351 and 352 forming respective lens groups respectively of 0 degree (straight seen), 30 degrees (perspective seen) and 70 degrees (perspective seen).

As shown in Fig. 49A, the beam from the objective optical system 341 forms an image I12 in the rear of the relay lens system the same as in the 26th embodiment by the relay lens system 342. Of the rays in the respective visual field directions forming the image I12 made in the rear of the relay lens system 342, the beams of the two pupils different in the visual field direction are respectively separated by the pupil separating optical member 344c arranged in the rear of the pupil image forming lens 343.

This pupil separating optical member 344c is, for example, a prism arranged near the pupil P13 transmitted by the relay lens system 342 and formed as an image by the pupil image forming lens 343. The separated beams in the respective visual field directions are reflected respectively by the reflecting members 344a and 344b and are formed as images respectively on the image taking devices 346a and 346b through the lens systems 345a and 345b.

In this embodiment, by the pupil image forming lens 343 forming images of pupils, the optical axes in the respective visual field directions are made substantially parallel with the optical axis of the relay lens system 342 and the object point is formed as an image to infinity. By the way, the image may be formed so as not to be superimposed on one solid state image taking device.

According to this embodiment, images different in the visual field direction can be independently taken by plural solid state image taking devices and the number

of visual fields and the visual field direction can be easily selected by the objective optical system. Without an optical visual field direction switching means, images in all the visual field directions are taken in and taken. As in the illustrated example, in the formation using plural solid state image taking devices, the outputs of the respective image taking devices are selected by switching the switch and the signals are processed as determined and can be displayed.

In the formation utilizing one solid state image taking device, the respective images different in the visual field direction may be selected by a signal processing means connected to the later step. The picture image in only one visual field direction can be displayed in a monitor.

That is to say, in this embodiment, without moving the optical system or without optically switching the visual field direction, the visual field direction can be changed. Also, depending on the way of processing the signal, plural images in the visual field direction can be simultaneously displayed in one or plural monitors.

An example of designing an objective optical system is shown in Fig. 52. Also, an example of designing an objective optical system and relay lens system as combined is shown in Fig. 53. In the drawings, the reference numeral 354 represents an objective optical system and the reference numeral 355 represents a relay lens system. The lens data are mentioned in Table 14..

By the way, the same as in the 26th embodiment, the diaphragm determining the pupil may be in the

objective optical system, may be in the pupil position in the conjugate relay lens system or may be in the pupil position near the pupil dividing optical member.

In Fig. 49B is shown a modification of the 27th embodiment. In this modification, a pupil image P13 is formed as of dispersed beams or converged beams by the pupil image forming lens 356 provided instead of the pupil image forming lens 343, afocal beams are then formed by the lens 357 making the beams parallel and further the beams are formed as images by the image taking devices 346a and 346b through the image forming lenses 345a and 345b. In this modification, a reflexing prism as a pupil dividing optical member is unnecessary. The diaphragm may be arranged above the pupil position P13 in the drawing, in the relay lens system or in the pupil position in the objective optical system. The other same formations and operations as in the 27th embodiment shall bear the same reference numerals and shall not be explained here.

The 28th embodiment of the present invention shall be explained in the following with reference to Figs. 55 to 58B.

In the formation of the 28th embodiment, an image forming optical system and a solid state image taking device are provided the same as in the 27th embodiment and further an optical visual field direction switching means is arranged.

The objective optical system in this embodiment may be the pupil dividing system in the 26th embodiment or may be formed of the substantially afocal plural optical systems and rear optical systems in the 27th

embodiment. This embodiment is different from the above mentioned respective embodiments in the formation of the optical system and the like arranged in the rear of the relay lens system arranged in the rear of the objective optical system.

As shown in Fig. 55, the optical system in this embodiment comprises a lens system 361 for making the light which was once formed as an image by a relay lens system in the rear of the relay lens system not illustrated and then became dispersed beams in the respective visual field directions parallel with the optical axis of the relay lens, a pupil switching apparatus 362 as a selecting means switching the beams in the respective visual field directions made parallel in response to the respective pupils and arranged near the pupils to be formed as images through the lens system 361 and an image forming lens system 363 forming images of the rays selected by the pupil switching device 362 on the solid state image taking device 364.

The rays in the respective visual field directions forming the image I21 formed in the rear of the relay lens system are made parallel with the optical axis of the relay lens system by the lens system 361. By the switching apparatus 362 near the pupil position, the rays passing through the other images than in the visual field direction the observer wants to observe are intercepted. The intercepting means as a selecting means may be a mechanically moved shielding plate or may be a liquid crystal shutter switch to be on/off.

The selecting means may be such image rotator

365 as in Figs. 56A and 56B to be moved to switch the visual field direction. The reference numeral 366 represents an image forming lens system forming an image of the rays obtained by the image rotator 365 on the solid state image taking device. By the way, Figs. 56A and 56B show that the visual field direction is switched by moving the image rotator 365.

Also, as shown in Fig. 57, the selecting means may be moved to the position of the visual field direction wanted to be observed integrally with the image forming lens system 365 and solid state image taking device 364 to switch the visual field direction. Only the image in the selected visual field direction is formed on the solid state image forming device 364.

The effect of this embodiment is that the visual field direction can be changed in a small space.

By the way, in case the pupil and image made by the objective optical system are transmitted by the relay lens system and the pupil dividing means is arranged after the relay lens system, the brightness diaphragm 321 can be omitted.

The formations of the 27th and 28th embodiments have an image taking means and may be applied to an outside fitted camera connectable to the ocular optical system of the 26th embodiment. In this formation, the lens system 343 or 361 is replaced with the ocular optical system 324.

The optical system after the transmitting optical system combining utilizing the pupil division in the objective optical system and utilizing the eccentric

optical system can be selected either to have the ocular optical system and optical visual field direction switching means or to have none.

In the case of either utilizing the pupil division in the objective optical system of the present invention or utilizing the eccentric optical system, when the means of intercepting the other rays than in the required visual field direction are provided near the pupils in the respective visual field directions, even if the transmitting optical system is replaced with the solid state image taking device or image guide, the visual field direction variable endoscope will be able to be realized.

In the formation shown in Fig. 58A, a pupil switching apparatus 368 is provided near the pupil formed in the light path of the objective optical system 370 consisting of the front side lens group which is the same as the front side lens group 329a of the 26th embodiment and the rear side lens system 348 and a solid state image taking device 369 is arranged. The pupil switching apparatus 368 may be a liquid crystal shutter or the like.

Also, in the formation shown in Fig. 58B, an eccentric optical system 371 including the same optical system as the front optical system 347c shown in Fig. 50 is utilized.

Fig. 59A is a formation view of an optical system in the plural visual field direction type endoscope in the 29th embodiment. Fig. 59B is a formation view of an objective optical system made partly common.

The objective optical system in the 29th

embodiment is formed of plural lens groups provided for respective visual fields instead of the objective optical system 322 so that plural images may be formed by these lens groups. The other formations and operations which are the same as in the 26th embodiment shall bear the same reference numerals and shall not be explained here.

The objective optical system 373 shown in Fig. 59A is formed of plural (two in the illustrated example) independent lens groups. The relay lens system 323 and ocular optical system 324 are arranged in the rear of the objective optical system 373. By the way, the relay lens system 323 and ocular optical system may be replaced with an image forming optical system and solid state image taking device.

The objective optical system 373 may be formed of an independent optical system as in Fig. 59A and may have a part, that is, the prism on the distal end side made common as in the objective optical system 373' shown in Fig. 59B.

The plural images I31 and I32 formed by the objective optical system are transmitted rearward by the relay lens system 323 as a transmitting optical system. In the formation having the ocular optical system 324, as in Fig. 59A, the observer can simultaneously see the respective visual field directions with the eye placed in the pupil position 374.

On the other hand, in the formation of the image forming optical system and solid state image taking device, the plural images made in the rear of the relay lens system 323 are formed on one solid state image

taking device by the image forming lens. The effect by this formation can be technically comparatively easily realized by any optical system after the objective optical system and transmitting optical system.

By the way, in this embodiment, images may be formed on plural solid state image taking devices with the image forming magnification made large and the solid state image taking devices placed in the positions corresponding to the plural images.

The 30th embodiment shall be explained with reference to Fig. 60A. As shown in Fig. 60A, in the optical system of this embodiment, an image is formed on the solid state image taking device 370 through the lens system 343 which is arranged in the rear of the relay lens system 342 and whereby the light once formed as an image by the relay lens system 342 and then made dispersed beams in the respective visual field directions is made parallel with the optical axes of the relay lens system 342 and optical systems arranged along two optical axes in the rear of this lens system 343.

Equimultiple relay systems by the lens systems 371 and 372 are arranged along one optical axis of the two optical axes and an image is formed on the solid state image taking device 370 by the lens system 372.

Also, equimultiple relay systems are arranged on the other optical axis. That is to say, the prism 373 for bending the optical axis is arranged near the pupil formed through the lens system 374 and on the rear side of this prism 373 are arranged the lens system 374, prism 375, lens system 376, prism 377, lens system 378 and

mirror 379. The beam is reflected by this mirror 379 arranged at the point P of intersection of this optical system and the other optical axis with each other and forms an image on the solid state image taking device 370 through the lens system 372.

This mirror 379 is rotatable as illustrated. The visual field direction can be selected by switching to either of the state A indicated by the solid line and the state B indicated by the dotted line. The other formations are the same components as are explained in Fig. 49A.

In the inserted section of the rigid endoscope to which this embodiment is applied, the distance between the two optical axes can not help being so small as to be several millimeters due to the restriction of the outside diameter. As the image is formed on one solid state image taking device 370 after the lens system 343, in case one optical system is used the same as in the relay lens system 342, the beam will diagonally project into the solid state image taking device 370 and a color shading will be generated. In order to prevent this phenomenon, in this embodiment, one of the two optical axes is bent by the prisms 373, 375 and 377 on the rear side of the lens system 343 as in Fig. 60A so that the beams having passed respectively through the two optical axes may project vertically onto the image taking surface of the solid state image taking device 370 and the generation of the color shading may be controlled.

Fig. 60B shows a formation of a modification of Fig. 60A. The optical system in Fig. 60A is formed of

expanded lens systems 374', 376' and 378' expanding respectively the lens systems 374, 376 and 378 so that the image may be observed in a larger picture surface size with one of the optical systems having two visual field directions. When the formation is separated into the inserted section 380 and the camera adapter section 381 rotatably fitted to this inserted section 380 and the camera adapter section 381 is rotatably formed, the picture sizes in the respective visual field directions will be able to be selectively made large.

Fig. 61A shows the 31st embodiment. In this embodiment, objective optical systems 391 and 391' to be a pair on the respective optical axes separated by a distance D are provided on the distal end side of the inserted section 390 and the respective images by the optical objective systems 391 and 391' are transmitted to the rear side respectively by the relay optical systems 392 and 392'.

The image transmitted by the relay optical system 392 is formed on the solid state image taking device 370 by the equimultiple relay optical systems comprising the lens systems 371 and 372 the same as in Fig. 60A.

Also, the image transmitted by the relay optical system 392' is formed on the solid state image taking device 370 through the same relay systems as in Fig. 60A, that is, the equimultiple relay systems by the prism 373, lens system 374, prism 375, lens system 376, prism 377, lens system 378, mirror 379 and lens system 372.

The same as in the embodiment in Fig. 60A, as a

means of switching the two optical systems, a mirror 379 is provided at the point P at which the two optical axes intersect with each other. The visual field direction can be selected by this mirror 379.

In the modification shown in Fig. 61B, the lens systems 374, 376 and 378 forming the relay systems in Fig. 61A are formed respectively of the expanded lens systems 374', 376' and 378' so that one optical system, that is, the objective optical system 391' and relay optical system 392' of the two optical systems arranged within the inserted section 390 may be made thinner, the outside diameter of the inserted section may be made smaller and the insertability may be improved.

Also, when the formation is separated into the inserted section 390 and the camera adapter section 393 rotatably fitted to the rear end of this inserted section and the camera adapter section 393 is rotatably formed, the picture size will be able to be selectively varied.

By the way, the present invention is not limited to these embodiments and modifications and any embodiment or modification formed by combining parts of them belongs to the present invention.

Table 1 Lens data of the first embodiment

$r1 = \infty$	$d1 = 0.400$	$n1 = 1.7682$	$\nu1 = 71.8$
$r2 = \infty$	$d2 = 0.300$		
$r3 = 2.4658$	$d3 = 0.563$	$n2 = 1.883$	$\nu2 = 40.8$
$r4 = 0.7855$	$d4 = 0.453$		
$r5 = \infty$	$d5 = 0.400$	$n3 = 1.8061$	$\nu3 = 40.9$
$r6 = \infty(\text{pupil})$	$d6 = 3.340$	$n4 = 1.8061$	$\nu4 = 40.9$
$r7 = -2.7844$	$d7 = 0.300$		

r8 = -4.5712	d8 = 0.400	n5 = 1.62004	ν 5 = 36.3
r9 = 13.1850	d9 = 0.730	n6 = 1.788	ν 6 = 47.4
r10 = -3.7741	d10 = 0.300		
r11 = 6.2003	d11 = 1.949	n7 = 1.60311	ν 7 = 60.7
r12 = -1.6595	d12 = 0.409	n8 = 1.84666	ν 8 = 23.8
r13 = -2.4812	d13 = 0.306		
r14 = -2.3688	d14 = 0.400	n9 = 1.78472	ν 9 = 25.7
r15 = -82.9824	d15 = 0.400	n10 = 1.6968	ν 10 = 55.5
r16 = -7.6931	d16 = 7.500		
r17 = 17.7721	d17 = 38.862	n11 = 1.51633	ν 11 = 64.1
r18 = -8.3001	d18 = 6.881	n12 = 1.85026	ν 12 = 32.3
r19 = -24.9616	d19 = 0.941		
r20 = 36.2005	d20 = 1.000	n13 = 1.8061	ν 13 = 40.9
r21 = ∞	d21 = 10.265	n14 = 1.51633	ν 14 = 64.1
r22 = ∞	d22 = 1.000	n15 = 1.8061	ν 15 = 40.9
r23 = -36.2005	d23 = 0.914		
r24 = 24.9616	d24 = 6.881	n16 = 1.85026	ν 16 = 32.3
r25 = 8.3001	d25 = 38.862	n17 = 1.51633	ν 17 = 64.1
r26 = -17.7721	d26 = 10.000		
r27 = 17.7721	d27 = 38.862	n18 = 1.51633	ν 18 = 64.1
r28 = -8.3001	d28 = 6.881	n19 = 1.85026	ν 19 = 32.3
r29 = -24.9616	d29 = 0.914		
r30 = 36.2005	d30 = 1.000	n20 = 1.8061	ν 20 = 40.9
r31 = ∞	d31 = 10.265	n21 = 1.51633	ν 21 = 64.1
r32 = ∞	d32 = 1.000	n22 = 1.8061	ν 22 = 40.9
r33 = -36.2005	d33 = 0.914		
r34 = 24.9616	d34 = 6.881	n23 = 1.85026	ν 23 = 32.3
r35 = 8.3001	d35 = 38.862	n24 = 1.51633	ν 24 = 64.1
r36 = -17.7721	d36 = 10.000		
r37 = 17.7721	d37 = 38.862	n25 = 1.51633	ν 25 = 64.1

$r_{38} = -8.3001$ $d_{38} = 6.881$ $n_{26} = 1.85026$ $\nu_{26} = 32.3$
 $r_{39} = -24.9616$ $d_{39} = 0.914$
 $r_{40} = 36.2005$ $d_{40} = 1.000$ $n_{27} = 1.8061$ $\nu_{27} = 40.9$
 $r_{41} = \infty$ $d_{41} = 10.265$ $n_{28} = 1.51633$ $\nu_{28} = 64.1$
 $r_{42} = \infty$ $d_{42} = 1.000$ $n_{29} = 1.8061$ $\nu_{29} = 40.9$
 $r_{43} = -36.2005$ $d_{43} = 0.914$
 $r_{44} = 24.9616$ $d_{44} = 6.881$ $n_{30} = 1.85026$ $\nu_{30} = 32.3$
 $r_{45} = 8.3001$ $d_{45} = 38.862$ $n_{31} = 1.51633$ $\nu_{31} = 64.1$
 $r_{46} = -17.7721$ $d_{46} = 5.000$
 $r_{47} = \infty$ (image position)

Table 2 Lens data of the third embodiment

$r_1 = \infty$ $d_1 = 0.400$ $n_1 = 1.7682$ $\nu_1 = 71.8$
 $r_2 = \infty$ $d_2 = 0.300$
 $r_3 = 3.8772$ $d_3 = 1.527$ $n_2 = 1.883$ $\nu_2 = 40.8$
 $r_4 = 0.7999$ $d_4 = 0.449$
 $r_5 = \infty$ $d_5 = 0.400$ $n_3 = 1.8061$ $\nu_3 = 40.9$
 $r_6 = \infty$ (pupil) $d_6 = 2.774$ $n_4 = 1.8061$ $\nu_4 = 40.9$
 $r_7 = -2.6393$ $d_7 = 0.300$
 $r_8 = -4.4440$ $d_8 = 0.400$ $n_5 = 1.62004$ $\nu_5 = 36.3$
 $r_9 = 13.0243$ $d_9 = 0.643$ $n_6 = 1.788$ $\nu_6 = 47.4$
 $r_{10} = -3.4953$ $d_{10} = 0.300$
 $r_{11} = 6.6459$ $d_{11} = 1.858$ $n_7 = 1.60311$ $\nu_7 = 60.7$
 $r_{12} = -1.6646$ $d_{12} = 0.416$ $n_8 = 1.84666$ $\nu_8 = 23.8$
 $r_{13} = -2.4857$ $d_{13} = 0.300$
 $r_{14} = -2.4171$ $d_{14} = 0.400$ $n_9 = 1.78472$ $\nu_9 = 25.7$
 $r_{15} = -5.1842$ $d_{15} = 0.400$ $n_{10} = 1.6968$ $\nu_{10} = 55.5$
 $r_{16} = -5.8028$ $d_{16} = 7.500$
 $r_{17} = 17.0269$ $d_{17} = 39.876$ $n_{11} = 1.51633$ $\nu_{11} = 64.1$
 $r_{18} = -9.1442$ $d_{18} = 6.480$ $n_{12} = 1.85026$ $\nu_{12} = 32.3$
 $r_{19} = -25.2664$ $d_{19} = 0.300$

r20= 38.6357	d20= 1.000	n13=1.8061	ν 13=40.9
r21= ∞	d21=10.000	n14=1.51633	ν 14=64.1
r22= ∞	d22= 1.000	n15=1.8061	ν 15=40.9
r23=-38.6357	d23= 0.300		
r24= 25.2664	d24= 6.480	n16=1.85026	ν 16=32.3
r25= 9.1442	d25=39.876	n17=1.51633	ν 17=64.1
r26=-17.0269	d26=10.000		
r27= 17.0269	d27=39.876	n18=1.51633	ν 18=64.1
r28= -9.1442	d28= 6.480	n19=1.85026	ν 19=32.3
r29=-25.2664	d29= 0.300		
r30= 38.6357	d30= 1.000	n20=1.8061	ν 20=40.9
r31= ∞	d31=10.000	n21=1.51633	ν 21=64.1
r32= ∞	d32= 1.000	n22=1.8061	ν 22=40.9
r33=-38.6357	d33= 0.300		
r34= 25.2664	d34= 6.480	n23=1.85026	ν 23=32.3
r35= 9.1442	d35=39.876	n24=1.51633	ν 24=64.1
r36=-17.0269	d36=10.000		
r37= 17.0269	d37=39.876	n25=1.51633	ν 25=64.1
r38= -9.1442	d38= 6.480	n26=1.85026	ν 26=32.3
r39=-25.2664	d39= 0.300		
r40= 38.6357	d40= 1.000	n27=1.8061	ν 27=40.9
r41= ∞	d41=10.000	n28=1.51633	ν 28=64.1
r42= ∞	d42= 1.000	n29=1.8061	ν 29=40.9
r43=-38.6357	d43= 0.300		
r44= 25.2664	d44= 6.480	n30=1.85026	ν 30=32.3
r45= 9.1442	d45=39.876	n31=1.51633	ν 31=64.1
r46=-17.0269	d46= 5.001		

r47= ∞ (image posirion)

Table 3 Lens data of the forth embodiment

r1 = ∞	d1 = 0.400	n1 =1.7682	ν 1 =71.8
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r2 = ∞	d2 = 0.300		
r3 = 2.6660	d3 = 1.000	n2 = 1.883	ν 2 = 40.8
r4 = 0.6568	d4 = 0.465		
r5 = ∞	d5 = 0.400	n3 = 1.883	ν 3 = 40.8
r6 = ∞ (pupil)	d6 = 2.938	n4 = 1.883	ν 4 = 40.8
r7 = -2.9259	d7 = 0.300		
r8 = -10.3818	d8 = 0.400	n5 = 1.62004	ν 5 = 36.3
r9 = 15.1216	d9 = 0.562	n6 = 1.788	ν 6 = 47.4
r10 = -4.9186	d10 = 0.300		
r11 = 6.1372	d11 = 1.797	n7 = 1.618	ν 7 = 63.4
r12 = -1.8144	d12 = 1.075	n8 = 1.84666	ν 8 = 23.8
r13 = -2.6860	d13 = 0.300		
r14 = -2.2723	d14 = 0.615	n9 = 1.78472	ν 9 = 25.7
r15 = -14.0716	d15 = 0.437	n10 = 1.6968	ν 10 = 55.5
r16 = -4.9749	d16 = 7.500		
r17 = 18.4320	d17 = 37.230	n11 = 1.51633	ν 11 = 64.1
r18 = -8.3411	d18 = 6.671	n12 = 1.85026	ν 12 = 32.3
r19 = -24.0584	d19 = 0.300		
r20 = 36.1875	d20 = 1.000	n13 = 1.8061	ν 13 = 40.9
r21 = ∞	d21 = 10.000	n14 = 1.51633	ν 14 = 64.1
r22 = ∞	d22 = 1.000	n15 = 1.8061	ν 15 = 40.9
r23 = -36.1875	d23 = 0.300		
r24 = 24.0584	d24 = 6.671	n16 = 1.85026	ν 16 = 32.3
r25 = 8.3411	d25 = 37.230	n17 = 1.51633	ν 17 = 64.1
r26 = -18.4320	d26 = 10.000		
r27 = 18.4320	d27 = 37.230	n18 = 1.51633	ν 18 = 64.1
r28 = -8.3411	d28 = 6.671	n19 = 1.85026	ν 19 = 32.3
r29 = -24.0584	d29 = 0.300		
r30 = 36.1875	d30 = 1.000	n20 = 1.8061	ν 20 = 40.9
r31 = ∞	d31 = 10.000	n21 = 1.51633	ν 21 = 64.1

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r32= ∞	d32= 1.000	n22=1.8061	ν 22=40.9
r33=-36.1875	d33= 0.300		
r34= 24.0584	d34= 6.671	n23=1.85026	ν 23=32.3
r35= 8.3411	d35=37.230	n24=1.51633	ν 24=64.1
r36=-18.4320	d36=10.000		
r37= 18.4320	d37=37.230	n25=1.51633	ν 25=64.1
r38= -8.3411	d38= 6.671	n26=1.85026	ν 26=32.3
r39=-24.0584	d39= 0.300		
r40= 36.1875	d40= 1.000	n27=1.8061	ν 27=40.9
r41= ∞	d41=10.000	n28=1.51633	ν 28=64.1
r42= ∞	d42= 1.000	n29=1.8061	ν 29=40.9
r43=-36.1875	d43= 0.300		
r44= 24.0584	d44= 6.671	n30=1.85026	ν 30=32.3
r45= 8.3411	d45=37.230	n31=1.51633	ν 31=64.1
r46=-18.4320	d46= 5.000		
r47= ∞	d47= 6.000 (reflection plane)		
r48= ∞	d48= 9.000 (reflection plane)		
r49=-15.7631	d49= 4.949	n32=1.816	ν 32=46.6
r50= -8.9021	d50= 2.525		
r51= 9.9691	d51= 4.480	n33=1.72916	ν 33=54.7
r52=-16.7003	d52= 2.578	n34=1.7552	ν 34=27.5
r53= 4.2972	d53= 3.722		
r54= 52.6411	d54= 1.000	n35=1.5927	ν 35=35.3
r55=117.6536	d55= 7.067	n36=1.618	ν 36=63.4
r56=-77.9950	d56= 1.037		
r57= 8.7799	d57= 7.000	n37=1.72916	ν 37=54.7
r58= 13.9542	d58=49.995		
r59= ∞ (image position)			

Table 4 Lens data of the fifth embodiment

r1 = ∞	d1 = 0.400	n1 =1.7682	ν 1 =71.8
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r2 = ∞	d2 = 0.300		
r3 = 2.8586	d3 = 1.000	n2 = 1.883	ν 2 = 40.8
r4 = 0.7279	d4 = 0.466		
r5 = ∞	d5 = 0.400	n3 = 1.883	ν 3 = 40.8
r6 = ∞ (pipul)	d6 = 2.216	n4 = 1.883	ν 4 = 40.8
r7 = -2.9043	d7 = 0.300		
r8 = -5.6042	d8 = 0.400	n5 = 1.62004	ν 5 = 36.3
r9 = 5.6154	d9 = 0.888	n6 = 1.788	ν 6 = 47.4
r10 = -3.6606	d10 = 0.300		
r11 = 7.1344	d11 = 1.764	n7 = 1.618	ν 7 = 63.4
r12 = -1.7751	d12 = 0.597	n8 = 1.84666	ν 8 = 23.8
r13 = -2.5646	d13 = 0.302		
r14 = -2.1629	d14 = 0.400	n9 = 1.78472	ν 9 = 25.7
r15 = -4.7832	d15 = 0.400	n10 = 1.6968	ν 10 = 55.5
r16 = -3.9862	d16 = 7.500		
r17 = 18.1763	d17 = 37.730	n11 = 1.51633	ν 11 = 64.1
r18 = -8.5520	d18 = 6.670	n12 = 1.85026	ν 12 = 32.2
r19 = -23.4978	d19 = 0.300		
r20 = 39.1240	d20 = 1.000	n13 = 1.8061	ν 13 = 40.9
r21 = ∞	d21 = 10.000	n14 = 1.51633	ν 14 = 64.1
r22 = ∞	d22 = 1.000	n15 = 1.8061	ν 15 = 40.9
r23 = -39.1240	d23 = 0.300		
r24 = 23.4978	d24 = 6.670	n16 = 1.85026	ν 16 = 32.2
r25 = 8.5520	d25 = 37.730	n17 = 1.51633	ν 17 = 64.1
r26 = -18.1763	d26 = 10.000		
r27 = 18.1763	d27 = 37.730	n18 = 1.51633	ν 18 = 64.1
r28 = -8.5520	d28 = 6.670	n19 = 1.85026	ν 19 = 32.2
r29 = -23.4978	d29 = 0.300		
r30 = 39.1240	d30 = 1.000	n20 = 1.8061	ν 20 = 40.9
r31 = ∞	d31 = 10.000	n21 = 1.51633	ν 21 = 64.1

r32= ∞	d32= 1.000	n22=1.8061	ν 22=40.9
r33=-39.1240	d33= 0.300		
r34= 23.4978	d34= 6.670	n23=1.85026	ν 23=32.2
r35= 8.5520	d35= 37.730	n24=1.51633	ν 24=64.1
r36=-18.1763	d36= 10.000		
r37= 18.1763	d37= 37.730	n25=1.51633	ν 25=64.1
r38= -8.5520	d38= 6.670	n26=1.85026	ν 26=32.2
r39=-23.4978	d39= 0.300		
r40= 39.1240	d40= 1.000	n27=1.8061	ν 27=40.9
r41= ∞	d41= 10.000	n28=1.51633	ν 28=64.1
r42= ∞	d42= 1.000	n29=1.8061	ν 29=40.9
r43=-39.1240	d43= 0.300		
r44= 23.4978	d44= 6.670	n30=1.85026	ν 30=32.2
r45= 8.5520	d45= 37.730	n31=1.51633	ν 31=64.1
r46=-18.1763	d46= 15.000		
r47=-15.9408	d47= 7.000	n32=1.816	ν 32=46.6
r48=-10.5614	d48= 1.898		
r49= 20.0434	d49= 1.000	n33=1.72916	ν 33=54.7
r50= 11.2226	d50= 1.852	n34=1.7552	ν 34=27.5
r51= 8.3607	d51= 6.099		
r52=-24.1926	d52= 3.535	n35=1.5927	ν 35=35.3
r53= 9.6335	d53= 9.958	n36=1.618	ν 36=63.4
r54=-27.0337	d54= 0.300		
r55= 22.5105	d55= 7.000	n37=1.72916	ν 37=54.7
r56=317.0029	d56=102.172		
r57= ∞ (image position)			

Table 5 Lens data of the sixth embodiment

r1 = ∞	d1 = 0.400	n1 =1.7682	ν 1 =71.8
r2 = ∞	d2 = 0.300		
r3 = 2.5311	d3 = 1.000	n2 =1.883	ν 2 =40.8

r4 = 0.6002	d4 = 0.483		
r5 = ∞	d5 = 0.492	n3 = 1.883	ν 3 = 40.8
r6 = ∞ (pupil)	d6 = 2.925	n4 = 1.883	ν 4 = 40.8
r7 = -2.9244	d7 = 0.300		
r8 = -20.1110	d8 = 0.500	n5 = 1.62004	ν 5 = 36.3
r9 = 10.9637	d9 = 0.607	n6 = 1.788	ν 6 = 47.4
r10 = -6.2777	d10 = 0.300		
r11 = 6.1192	d11 = 1.860	n7 = 1.618	ν 7 = 63.4
r12 = -1.8981	d12 = 0.810	n8 = 1.84666	ν 8 = 23.8
r13 = -2.7109	d13 = 0.302		
r14 = -2.2811	d14 = 0.400	n9 = 1.78472	ν 9 = 25.7
r15 = -13.8892	d15 = 1.289	n10 = 1.6968	ν 10 = 55.5
r16 = -5.4300	d16 = 7.500		
r17 = 18.4228	d17 = 37.662	n11 = 1.51633	ν 11 = 64.1
r18 = -8.3677	d18 = 6.665	n12 = 1.85026	ν 12 = 32.3
r19 = -24.4094	d19 = 0.300		
r20 = 35.7941	d20 = 1.000	n13 = 1.8061	ν 13 = 40.9
r21 = ∞	d21 = 10.000	n14 = 1.51633	ν 14 = 64.1
r22 = ∞	d22 = 1.000	n15 = 1.8061	ν 15 = 40.9
r23 = -35.7941	d23 = 0.300		
r24 = 24.4094	d24 = 6.665	n16 = 1.85026	ν 16 = 32.3
r25 = 8.3677	d25 = 37.662	n17 = 1.51633	ν 17 = 64.1
r26 = -18.4228	d26 = 10.000		
r27 = 18.4228	d27 = 37.662	n18 = 1.51633	ν 18 = 64.1
r28 = -8.3677	d28 = 6.665	n19 = 1.85026	ν 19 = 32.3
r29 = -24.4094	d29 = 0.300		
r30 = 35.7941	d30 = 1.000	n20 = 1.8061	ν 20 = 40.9
r31 = ∞	d31 = 10.000	n21 = 1.51633	ν 21 = 64.1
r32 = ∞	d32 = 1.000	n22 = 1.8061	ν 22 = 40.9
r33 = -35.7941	d33 = 0.300		

r34= 24.4094	d34= 6.665	n23=1.85026	ν 23=32.3
r35= 8.3677	d35= 37.662	n24=1.51633	ν 24=64.1
r36=-18.4228	d36= 10.000		
r37= 18.4228	d37= 37.662	n25=1.51633	ν 25=64.1
r38= -8.3677	d38= 6.665	n26=1.85026	ν 26=32.3
r39=-24.4094	d39= 0.300		
r40= 35.7941	d40= 1.000	n27=1.8061	ν 27=40.9
r41= ∞	d41= 10.000	n28=1.51633	ν 28=64.1
r42= ∞	d42= 1.000	n29=1.8061	ν 29=40.9
r43=-35.7941	d43= 0.300		
r44= 24.4094	d44= 6.665	n30=1.85026	ν 30=32.3
r45= 8.3677	d45= 37.662	n31=1.51633	ν 31=64.1
r46=-18.4228	d46= 5.000		
r47= ∞	d47= 11.000		
r48=-10.3813	d48= 5.655	n32=1.816	ν 32=46.6
r49= -8.8890	d49= 0.483		
r50= 7.4696	d50= 3.769	n33=1.72916	ν 33=54.7
r51=181.6429	d51= 2.093	n34=1.7552	ν 34=27.5
r52= 4.4460	d52= 3.047		
r53=-30.7603	d53= 1.001	n35=1.5927	ν 35=35.3
r54= 41.5845	d54= 1.706	n36=1.618	ν 36=63.4
r55=-17.8259	d55= 0.342		
r56= 7.9775	d56= 5.749	n37=1.72916	ν 37=54.7
r57= 12.6259	d57= 39.986		
r58= ∞ (image position)			

Table 6 Lens data of the tenth embodiment

r1 = ∞	d1 = 0.400	n1 =1.7682	ν 1 =71.8
r2 = ∞	d2 = 0.500		
r3 =-15.1509	d3 = 0.500	n2 =1.883	ν 2 =40.8
r4 = 1.8541	d4 = 0.400		

r5 = ∞	d5 = 1.471	n3 = 1.8061	ν 3 = 40.9
r6 = ∞ (pupil)	d6 = 8.000	n4 = 1.8061	ν 4 = 40.9
r7 = -6.3400	d7 = 0.300		
r8 = 29.8778	d8 = 6.980	n5 = 1.60311	ν 5 = 60.7
r9 = -76.5455	d9 = 2.000		
r10 = 11.8863	d10 = 12.000	n6 = 1.60311	ν 6 = 60.7
r11 = -14.2286	d11 = 1.000	n7 = 1.84666	ν 7 = 23.8
r12 = 6.6719	d12 = 1.327		
r13 = 16.2399	d13 = 1.000	n8 = 1.84666	ν 8 = 23.8
r14 = 6.8781	d14 = 2.641	n9 = 1.60311	ν 9 = 60.7
r15 = -16.3999	d15 = 0.300		
r16 = 9.6243	d16 = 2.045	n10 = 1.72916	ν 10 = 54.7
r17 = 42.1473	d17 = 12.000		
r18 = 20.3224	d18 = 28.648	n11 = 1.51633	ν 11 = 64.1
r19 = -9.1270	d19 = 1.000	n12 = 1.85026	ν 12 = 32.3
r20 = -17.5105	d20 = 0.300		
r21 = 37.3211	d21 = 2.038	n13 = 1.8061	ν 13 = 40.9
r22 = ∞	d22 = 25.393	n14 = 1.51633	ν 14 = 64.1
r23 = ∞	d23 = 2.038	n15 = 1.8061	ν 15 = 40.9
r24 = -37.3211	d24 = 0.300		
r25 = 17.5105	d25 = 1.000	n16 = 1.85026	ν 16 = 32.3
r26 = 9.1270	d26 = 28.648	n17 = 1.51633	ν 17 = 64.1
r27 = -20.3224	d27 = 14.000		
r28 = 20.3224	d28 = 28.648	n18 = 1.51633	ν 18 = 64.1
r29 = -9.1270	d29 = 1.000	n19 = 1.85026	ν 19 = 32.3
r30 = -17.5105	d30 = 0.300		
r31 = 37.3211	d31 = 2.038	n20 = 1.8061	ν 20 = 40.9
r32 = ∞	d32 = 25.393	n21 = 1.51633	ν 21 = 64.1
r33 = ∞	d33 = 2.038	n22 = 1.8061	ν 22 = 40.9
r34 = -37.3211	d34 = 0.300		

r35= 17.5105	d35= 1.000	n23=1.85026	ν 23=32.3
r36= 9.1270	d36= 28.648	n24=1.51633	ν 24=64.1
r37=-20.3224	d37= 14.000		
r38= 20.3224	d38= 28.648	n25=1.51633	ν 25=64.1
r39= -9.1270	d39= 1.000	n26=1.85026	ν 26=32.3
r40=-17.5105	d40= 0.300		
r41= 37.3211	d41= 2.038	n27=1.8061	ν 27=40.9
r42= ∞	d42= 25.393	n28=1.51633	ν 28=64.1
r43= ∞	d43= 2.038	n29=1.8061	ν 29=40.9
r44=-37.3211	d44= 0.300		
r45= 17.5105	d45= 1.000	n30=1.85026	ν 30=32.3
r46= 9.1270	d46= 28.648	n31=1.51633	ν 31=64.1
r47=-20.3224	d47= 17.000		
r48=-14.8821	d48= 2.846	n32=1.72916	ν 32=54.7
r49= -8.8016	d49= 0.300		
r50= 15.1352	d50= 4.084	n33=1.618	ν 33=63.4
r51= -7.3338	d51= 1.000	n34=1.5927	ν 34=35.3
r52= 9.5056	d52= 4.000		
r53=-16.8952	d53= 2.000	n35=1.7552	ν 35=27.5
r54=-13.2379	d54= 2.000	n36=1.72916	ν 36=54.7
r55=-23.2387	d55= 0.300		
r56= 22.9913	d56= 2.000	n37=1.816	ν 37=46.6
r57= 89.7162	d57= 15.000		
r58= ∞	d58= 6.000 (reflection plane)		
r59= ∞	d59= 4.000 (reflection plane)		
r60= 22.5828	d60= 1.000	n38=1.78472	ν 38=25.7
r61= 6.1627	d61= 3.276	n39=1.55963	ν 39=61.2
r62= 9.4965	d62= 1.747		
r63= 13.6433	d63= 3.041	n40=1.60311	ν 40=60.7
r64=-11.6980	d64= 29.780		

r65= ∞ (image position)

Table 7 Lens data of the eleventh embodiment

r1 = ∞	d1 = 0.400	n1 = 1.7682	ν 1 = 71.8
r2 = ∞	d2 = 0.500		
r3 = -27.1944	d3 = 0.500	n2 = 1.883	ν 2 = 40.8
r4 = 1.6149	d4 = 0.400		
r5 = ∞	d5 = 0.648	n3 = 1.8061	ν 3 = 40.9
r6 = ∞ (pupil)	d6 = 8.000	n4 = 1.8061	ν 4 = 40.9
r7 = -5.9410	d7 = 0.300		
r8 = 34.5218	d8 = 1.405	n5 = 1.60311	ν 5 = 60.7
r9 = -44.4283	d9 = 1.636		
r10 = 10.5798	d10 = 11.910	n6 = 1.60311	ν 6 = 60.7
r11 = -9.6402	d11 = 1.000	n7 = 1.84666	ν 7 = 23.8
r12 = 5.5533	d12 = 1.354		
r13 = 16.9402	d13 = 1.000	n8 = 1.84666	ν 8 = 23.8
r14 = 5.6237	d14 = 2.775	n9 = 1.60311	ν 9 = 60.7
r15 = -11.8857	d15 = 0.300		
r16 = 9.6717	d16 = 2.054	n10 = 1.72916	ν 10 = 54.7
r17 = 67.8305	d17 = 12.000		
r18 = 19.4101	d18 = 30.497	n11 = 1.51633	ν 11 = 64.1
r19 = -9.3708	d19 = 1.000	n12 = 1.85026	ν 12 = 32.3
r20 = -18.4223	d20 = 0.300		
r21 = 37.3503	d21 = 1.000	n13 = 1.8061	ν 13 = 40.9
r22 = ∞	d22 = 29.679	n14 = 1.51633	ν 14 = 64.1
r23 = ∞	d23 = 1.000	n15 = 1.8061	ν 15 = 40.9
r24 = -37.3503	d24 = 0.300		
r25 = 18.4223	d25 = 1.000	n16 = 1.85026	ν 16 = 32.3
r26 = 9.3708	d26 = 30.497	n17 = 1.51633	ν 17 = 64.1
r27 = -19.4101	d27 = 14.000		
r28 = 19.4101	d28 = 30.497	n18 = 1.51633	ν 18 = 64.1

r29= -9.3708	d29= 1.000	n19=1.85026	ν 19=32.3
r30=-18.4223	d30= 0.300		
r31= 37.3503	d31= 1.000	n20=1.8061	ν 20=40.9
r32= ∞	d32= 29.679	n21=1.51633	ν 21=64.1
r33= ∞	d33= 1.000	n22=1.8061	ν 22=40.9
r34=-37.3503	d34= 0.300		
r35= 18.4223	d35= 1.000	n23=1.85026	ν 23=32.3
r36= 9.3708	d36= 30.497	n24=1.51633	ν 24=64.1
r37=-19.4101	d37= 14.000		
r38= 19.4101	d38= 30.497	n25=1.51633	ν 25=64.1
r39= -9.3708	d39= 1.000	n26=1.85026	ν 26=32.3
r40=-18.4223	d40= 0.300		
r41= 37.3503	d41= 1.000	n27=1.8061	ν 27=40.9
r42= ∞	d42= 29.679	n28=1.51633	ν 28=64.1
r43= ∞	d43= 1.000	n29=1.8061	ν 29=40.9
r44=-37.3503	d44= 0.300		
r45= 18.4223	d45= 1.000	n30=1.85026	ν 30=32.3
r46= 9.3708	d46= 30.497	n31=1.51633	ν 31=64.1
r47=-19.4101	d47= 19.000		
r48=-14.3213	d48= 7.000	n32=1.72916	ν 32=54.7
r49=-11.0960	d49= 0.300		
r50= 33.1140	d50= 1.047	n33=1.618	ν 33=63.4
r51= 9.1082	d51= 7.000	n34=1.5927	ν 34=35.3
r52= 67.5887	d52= 3.277		
r53= -9.9528	d53= 7.000	n35=1.7552	ν 35=27.5
r54= 41.3894	d54= 10.000	n36=1.72916	ν 36=54.7
r55=-19.8178	d55= 3.000		
r56=-63.2683	d56= 7.000	n37=1.816	ν 37=46.6
r57=-41.6536	d57= 6.621		
r58= 20.1426	d58= 2.426	n38=1.51633	ν 38=64.1

r25=-19.9468	d25= 14.000		
r26= 19.9468	d26= 30.262	n17=1.51633	ν 17=64.1
r27= -9.0769	d27= 1.018	n18=1.85026	ν 18=32.3
r28=-18.5715	d28= 0.300		
r29= 34.7626	d29= 3.093	n19=1.8061	ν 19=40.9
r30= ∞	d30= 19.606	n20=1.51633	ν 20=64.1
r31= ∞	d31= 3.093	n21=1.8061	ν 21=40.9
r32=-34.7626	d32= 0.300		
r33= 18.5715	d33= 1.018	n22=1.85026	ν 22=32.3
r34= 9.0769	d34= 30.262	n23=1.51633	ν 23=64.1
r35=-19.9468	d35= 14.000		
r36= 19.9468	d36= 30.262	n24=1.51633	ν 24=64.1
r37= -9.0769	d37= 1.018	n25=1.85026	ν 25=32.3
r38=-18.5715	d38= 0.300		
r39= 34.7626	d39= 3.093	n26=1.8061	ν 26=40.9
r40= ∞	d40= 19.606	n27=1.51633	ν 27=64.1
r41= ∞	d41= 3.093	n28=1.8061	ν 28=40.9
r42=-34.7626	d42= 0.300		
r43= 18.5715	d43= 1.018	n29=1.85026	ν 29=32.3
r44= 9.0769	d44= 30.262	n30=1.51633	ν 30=64.1
r45=-19.9468	d45= 19.000		
r46=-11.8408	d46= 5.820	n31=1.72916	ν 31=54.7
r47= -9.1946	d47= 0.300		
r48= 24.0775	d48= 10.000	n32=1.618	ν 32=63.4
r49=-26.2109	d49= 7.000	n33=1.5927	ν 33=35.3
r50= 63.4749	d50= 3.000		
r51= -8.3204	d51= 5.376	n34=1.7552	ν 34=27.5
r52=-38.8722	d52= 10.000	n35=1.72916	ν 35=54.7
r53=-19.1304	d53= 3.000		
r54=-83.1506	d54= 7.000	n36=1.816	ν 36=46.6

r55=-41.8244 d55= 8.346
 r56=-26.1283 d56= 4.325 n37=1.51633 ν 37=64.1
 r57= -7.8805 d57= 4.552 n38=1.78472 ν 38=25.7
 r58=-14.4880 d58= 0.300
 r59= 31.7804 d59= 5.000 n39=1.5725 ν 39=57.8
 r60=6326.3883 d60= 36.032
 r61= ∞ (image position)

Table 9 Lens data of the thirteenth embodiment

r1 = ∞	d1 = 0.400	n1 = 1.7682	ν 1 = 71.8
r2 = ∞	d2 = 0.500		
r3 = 14.7408	d3 = 0.500	n2 = 1.883	ν 2 = 40.8
r4 = 1.5441	d4 = 0.400		
r5 = ∞	d5 = 0.572	n3 = 1.8061	ν 3 = 40.9
r6 = ∞ (pupil)	d6 = 7.966	n4 = 1.8061	ν 4 = 40.9
r7 = -5.9996	d7 = 0.300		
r8 = 38.8172	d8 = 1.360	n5 = 1.60311	ν 5 = 60.7
r9 = -54.0250	d9 = 1.040		
r10 = 10.8354	d10 = 11.720	n6 = 1.60311	ν 6 = 60.7
r11 = -36.1554	d11 = 1.000	n7 = 1.84666	ν 7 = 23.8
r12 = 5.7085	d12 = 1.444		
r13 = 17.6383	d13 = 1.000	n8 = 1.84666	ν 8 = 23.8
r14 = 5.3388	d14 = 3.339	n9 = 1.60311	ν 9 = 60.7
r15 = -10.4808	d15 = 0.300		
r16 = 10.4139	d16 = 2.316	n10 = 1.72916	ν 10 = 54.7
r17 = 1299.7086	d17 = 12.000		
r18 = 20.9531	d18 = 28.137	n11 = 1.51633	ν 11 = 64.1
r19 = -9.0377	d19 = 1.029	n12 = 1.85026	ν 12 = 32.3
r20 = -17.1424	d20 = 0.300		
r21 = 37.8341	d21 = 1.462	n13 = 1.8061	ν 13 = 40.9
r22 = ∞	d22 = 26.759	n14 = 1.51633	ν 14 = 64.1

r23= ∞	d23= 1.462	n15=1.8061	ν 15=40.9
r24=-37.8341	d24= 0.300		
r25= 17.1424	d25= 1.029	n16=1.85026	ν 16=32.3
r26= 9.0377	d26= 28.137	n17=1.51633	ν 17=64.1
r27=-20.9531	d27= 14.000		
r28= 20.9531	d28= 28.137	n18=1.51633	ν 18=64.1
r29= -9.0377	d29= 1.029	n19=1.85026	ν 19=32.3
r30=-17.1424	d30= 0.300		
r31= 37.8341	d31= 1.462	n20=1.8061	ν 20=40.9
r32= ∞	d32= 26.759	n21=1.51633	ν 21=64.1
r33= ∞	d33= 1.462	n22=1.8061	ν 22=40.9
r34=-37.8341	d34= 0.300		
r35= 17.1424	d35= 1.029	n23=1.85026	ν 23=32.3
r36= 9.0377	d36= 28.137	n24=1.51633	ν 24=64.1
r37=-20.9531	d37= 14.000		
r38= 20.9531	d38= 28.137	n25=1.51633	ν 25=64.1
r39= -9.0377	d39= 1.029	n26=1.85026	ν 26=32.3
r40=-17.1424	d40= 0.300		
r41= 37.8341	d41= 1.462	n27=1.8061	ν 27=40.9
r42= ∞	d42= 26.759	n28=1.51633	ν 28=64.1
r43= ∞	d43= 1.462	n29=1.8061	ν 29=40.9
r44=-37.8341	d44= 0.300		
r45= 17.1424	d45= 1.029	n30=1.85026	ν 30=32.3
r46= 9.0377	d46= 28.137	n31=1.51633	ν 31=64.1
r47=-20.9531	d47= 19.000		
r48=-13.4332	d48= 7.000	n32=1.72916	ν 32=54.7
r49=-11.0047	d49= 0.300		
r50= 17.1878	d50= 5.837	n33=1.618	ν 33=63.4
r51= 57.8341	d51= 7.000	n34=1.5927	ν 34=35.3
r52= 38.7072	d52= 4.174		

$r53 = -8.1955$ $d53 = 6.919$ $n35 = 1.7552$ $\nu 35 = 27.5$
 $r54 = 42.2429$ $d54 = 10.000$ $n36 = 1.72916$ $\nu 36 = 54.7$
 $r55 = -19.4465$ $d55 = 0.300$
 $r56 = 944.8567$ $d56 = 4.699$ $n37 = 1.816$ $\nu 37 = 46.6$
 $r57 = -50.3836$ $d57 = 18.931$
 $r58 = 136.6914$ $d58 = 5.000$ $n38 = 1.51633$ $\nu 38 = 64.1$
 $r59 = -21.5686$ $d59 = 5.000$ $n39 = 1.78472$ $\nu 39 = 25.7$
 $r60 = -47.7722$ $d60 = 3.000$
 $r61 = 24.4617$ $d61 = 5.000$ $n40 = 1.5725$ $\nu 40 = 57.8$
 $r62 = 207.2457$ $d62 = 24.000$
 $r63 = \infty(\text{image position})$

Table 10 Lens data of the twenty third embodiment

$r1 = \infty$ $d1 = 0.4$ $n1 = 1.769000$ $\nu 1 = 71.8$
 $r2 = \infty$ $d2 = 0.3$
 $r3 = \infty$ $d3 = 0.5$ $n2 = 1.784720$ $\nu 2 = 25.8$
 $r4 = 2.18120$ $d4 = 0.8$
 $r5 = \infty$ $d5 = 6.524779$ $n3 = 1.806098$ $\nu 3 = 40.9$
 $r6 = \infty$ $d6 = 0.000000$ $n4 = 1.806098$ $\nu 4 = 40.9$
 $r7 = \infty$ $d7 = 10.000000$ $n5 = 1.806098$ $\nu 5 = 40.9$
 $r8 = -18.90821$ $d8 = 2.000000$
 $r9 = 11.34978$ $d9 = 7.000000$ $n6 = 1.589130$ $\nu 6 = 61.2$
 $r10 = -6.85269$ $d10 = 7.000000$ $n7 = 1.784718$ $\nu 7 = 25.7$
 $r11 = -9.21315$ $d11 = 1.757525$
 $r12 = -5.83605$ $d12 = 1.329338$ $n8 = 1.784718$ $\nu 8 = 25.7$
 $r13 = 21.54459$ $d13 = 5.000000$ $n9 = 1.772499$ $\nu 9 = 49.6$
 $r14 = -9.87710$ $d14 = 0.300000$
 $r15 = 23.34659$ $d15 = 5.000000$ $n10 = 1.729157$ $\nu 10 = 54.7$
 $r16 = -46.95906$ $d16 = 9.832604$

Table 11 Lens data of the twenty fort embodiment

$r1 = \infty$ $d1 = 0.4$ $n1 = 1.769000$ $\nu 1 = 71.8$

r2 = ∞	d2 = 0.3		
r3 = ∞	d3 = 0.5	n2 = 1.784720	ν 2 = 25.8
r4 = 2.24795	d4 = 0.8		
r5 = ∞	d5 = 26.000000	n3 = 1.806098	ν 3 = 40.9
r6 = ∞	d6 = 0.000000	n4 = 1.806098	ν 4 = 40.9
r7 = ∞	d7 = 28.856575	n5 = 1.806098	ν 5 = 40.9
r8 = -36.97230	d8 = 15.000000		
r9 = 10.27055	d9 = 13.872951	n6 = 1.496999	ν 6 = 31.6
r10 = -6.76542	d10 = 8.669330	n7 = 1.846660	ν 7 = 23.8
r11 = -12.08426	d11 = 4.358284		
r12 = -6.61021	d12 = 3.807170	n8 = 1.846660	ν 8 = 23.8
r13 = -10.66959	d13 = 4.004968	n9 = 1.772499	ν 9 = 49.6
r14 = -10.95412	d14 = 3.679284		
r15 = -13.63092	d15 = 8.940710	n10 = 1.729157	ν 10 = 54.7
r16 = -11.40751	d16 = 9.956806		
r17 = 18.08889	d17 = 37.945337	n11 = 1.516330	ν 11 = 64.1
r18 = -8.56598	d18 = 6.671087	n12 = 1.850259	ν 12 = 32.3
r19 = -23.41526	d19 = 0.300000		
r20 = 39.63203	d20 = 1.000000	n13 = 1.806098	ν 13 = 40.9
r21 = ∞	d21 = 5.000000	n14 = 1.516330	ν 14 = 64.1
r22 = ∞	d22 = 5.000000	n15 = 1.516330	ν 15 = 64.1
r23 = ∞	d23 = 1.000000	n16 = 1.806098	ν 16 = 40.9
r24 = -39.63203	d24 = 0.300000		
r25 = 23.41526	d25 = 6.671087	n17 = 1.850259	ν 17 = 32.3
r26 = 8.56598	d26 = 37.945337	n18 = 1.516330	ν 18 = 64.1
r27 = -18.08889	d27 = 10.000000		
r28 = 18.08889	d28 = 37.945337	n19 = 1.516330	ν 19 = 64.1
r29 = -8.56598	d29 = 6.671087	n20 = 1.850259	ν 20 = 32.3
r30 = -23.41526	d30 = 0.300000		
r31 = 39.63203	d31 = 1.000000	n21 = 1.806098	ν 21 = 40.9

r32= ∞	d32= 5.000000	n22= 1.516330	ν 22= 64.1
r33= ∞	d33= 5.000000	n23= 1.516330	ν 23= 64.1
r34= ∞	d34= 1.000000	n24= 1.806098	ν 24= 40.9
r35=-39.63203	d35= 0.300000		
r36= 23.41526	d36= 6.671087	n25= 1.850259	ν 25= 32.3
r37= 8.56598	d37=37.945337	n26= 1.516330	ν 26= 64.1
r38=-18.08889	d38=10.000000		
r39= 18.08889	d39=37.945337	n27= 1.516330	ν 27= 64.1
r40= -8.56598	d40= 6.671087	n28= 1.850259	ν 28= 32.3
r41=-23.41526	d41= 0.300000		
r42= 39.63203	d42= 1.000000	n29= 1.806098	ν 29= 40.9
r43= ∞	d43= 5.000000	n30= 1.516330	ν 30= 64.1
r44= ∞	d44= 5.000000	n31= 1.516330	ν 31= 64.1
r45= ∞	d45= 1.000000	n32= 1.806098	ν 32= 40.9
r46=-39.63203	d46= 0.300000		
r47= 23.41526	d47= 6.671087	n33= 1.850259	ν 33= 32.3
r48= 8.56598	d48=37.945337	n34= 1.516330	ν 34= 64.1
r49=-18.08889	d49=15.000000		
r50=-15.76035	d50= 7.000000	n35= 1.816000	ν 35= 46.6
r51=-10.49216	d51= 0.300000		
r52= 19.16924	d52= 1.000000	n36= 1.729157	ν 36= 54.7
r53= 10.37555	d53= 1.000000	n37= 1.755199	ν 37= 27.5
r54= 8.20791	d54= 6.363656		
r55=-24.61446	d55= 3.366619	n38= 1.592701	ν 38= 35.3
r56= 9.99541	d56= 9.925109	n39= 1.618000	ν 39= 63.4
r57=-27.28005	d57= 0.547138		
r58= 22.89857	d58= 7.000000	n40= 1.729157	ν 40= 54.7
r59=465.13444	d59=100.501554		

Table 12 Lens data of the twenty fifth embodiment

R D N ν

r1 = ∞	d1 = 0.400000	n1 = 1.769000	ν 1 = 71.8
r2 = ∞	d2 = 0.300000		
r3 = -5.97394	d3 = 0.500000	n2 = 1.784720	ν 2 = 25.8
r4 = -81.88587	d4 = 0.400000		
r5 = ∞	d5 = 7.000000	n3 = 1.806098	ν 3 = 40.9
r6 = ∞	d6 = 0.000000	n4 = 1.806098	ν 4 = 40.9
r7 = ∞	d7 = 5.000000	n5 = 1.806098	ν 5 = 40.9
r8 = -19.02807	d8 = 0.300000		
r9 = 19.68776	d9 = 1.500000	n6 = 1.603112	ν 6 = 60.7
r10 = -143.32901	d10 = 0.300000		
r11 = 8.84970	d11 = 2.000000	n7 = 1.603112	ν 7 = 60.7
r12 = 205.54794	d12 = 2.000000	n8 = 1.846660	ν 8 = 23.8
r13 = 7.54926	d13 = 3.000000		
r14 = 11.00667	d14 = 3.000000	n9 = 1.846660	ν 9 = 23.8
r15 = 6.70344	d15 = 2.697123	n10 = 1.603112	ν 10 = 60.7
r16 = -29.22995	d16 = 0.300000		
r17 = 25.03133	d17 = 5.000000	n11 = 1.729157	ν 11 = 54.7
r18 = -19.09934	d18 = 14.067359		
r19 = 20.97714	d19 = 31.002854	n12 = 1.516330	ν 12 = 64.1
r20 = -9.61884	d20 = 1.000000	n13 = 1.850259	ν 13 = 32.3
r21 = -18.35394	d21 = 0.300000		
r22 = 39.59182	d22 = 1.000000	n14 = 1.806098	ν 14 = 40.9
r23 = ∞	d23 = 12.733214	n15 = 1.516330	ν 15 = 64.1
r24 = ∞	d24 = 12.733214	n16 = 1.516330	ν 16 = 64.1
r25 = ∞	d25 = 1.000000	n17 = 1.806098	ν 17 = 40.9
r26 = -39.59182	d26 = 0.300000		
r27 = 18.35394	d27 = 1.000000	n18 = 1.850259	ν 18 = 32.3
r28 = 9.61884	d28 = 31.002854	n19 = 1.516330	ν 19 = 64.1
r29 = -20.97714	d29 = 13.999522		
r30 = 20.97714	d30 = 31.002854	n20 = 1.516330	ν 20 = 64.1

r31=	-9.61884	d31=	1.000000	n21=	1.850259	ν 21=	32.3
r32=	-18.35394	d32=	0.300000				
r33=	39.59182	d33=	1.000000	n22=	1.806098	ν 22=	40.9
r34=	∞	d34=	12.733214	n23=	1.516330	ν 23=	64.1
r35=	∞	d35=	12.733214	n24=	1.516330	ν 24=	64.1
r36=	∞	d36=	1.000000	n25=	1.806098	ν 25=	40.9
r37=	-39.59182	d37=	0.300000				
r38=	18.35394	d38=	1.000000	n26=	1.850259	ν 26=	32.3
r39=	9.61884	d39=	31.002854	n27=	1.516330	ν 27=	64.1
r40=	-20.97714	d40=	22.951000				
r41=	51.24000	d41=	4.900000	n28=	1.712995	ν 28=	53.9
r42=	-30.80800	d42=	0.350000				
r43=	15.16600	d43=	4.930000	n29=	1.617001	ν 29=	62.8
r44=	47.26000	d44=	1.650000	n30=	1.592701	ν 30=	35.3
r45=	10.61000	d45=	7.000000				
r46=	-8.87100	d46=	2.070000	n31=	1.755199	ν 31=	27.5
r47=	-42.79500	d47=	7.380000	n32=	1.696800	ν 32=	56.5
r48=	-13.94800	d48=	0.480000				
r49=	∞	d49=	4.700000	n33=	1.804000	ν 33=	46.6
r50=	-45.75100	d50=	8.660000				
r51=	47.10400	d51=	3.500000	n34=	1.516330	ν 34=	64.1
r52=	-22.01500	d52=	1.500000	n35=	1.784718	ν 35=	25.7
r53=	-48.13700	d53=	1.000000				
r54=	79.15800	d54=	3.000000	n36=	1.572501	ν 36=	57.8
r55=	-79.15800	d55=	32.098487				

Table 13 Lens data of the twenty sixth embodiment

r1 =	∞	d1 =	1.0	n1 =	1.51633	ν 1 =	64.15
r2 =	∞	d2 =	0.3				
r3 =	∞	d3 =	1.5	n2 =	1.72916	ν 2 =	54.68
r4 =	4.4560	d4 =	2.5				

r5 = ∞	d5 = 22.02	n3 = 1.88300	ν 3 = 40.78
r6 = ∞ (pipul)	d6 = 5.39	n4 = 1.88300	ν 4 = 40.78
r7 = -10.3990	d7 = 1.02		
r8 = -8.6190	d8 = 2.0	n5 = 1.62004	ν 5 = 36.25
r9 = ∞	d9 = 3.5	n6 = 1.788	ν 6 = 47.38
r10 = -14.1680	d10 = 2.28		
r11 = 24.1810	d11 = 6.14	n7 = 1.51633	ν 7 = 64.15
r12 = -11.7470	d12 = 3.0	n8 = 1.78472	ν 8 = 25.71
r13 = ∞	d13 = 8.65		
r14 = 38.2890	d14 = 3.0	n9 = 1.59551	ν 9 = 39.21
r15 = 11.4220	d15 = 6.0	n10 = 1.51633	ν 10 = 64.15
r16 = -19.2720	d16 = 10.0		

Table 14 Lens data of the twenty seventh embodiment

r1 = ∞	d1 = 0.4	n1 = 1.7682	ν 1 = 71.8
r2 = ∞	d2 = 0.5		
r3 = -12.44196	d3 = 0.5	n2 = 1.883	ν 2 = 40.8
r4 = 3.50665	d4 = 0.4		
r5 = ∞	d5 = 7.0	n3 = 1.80610	ν 3 = 40.9
r6 = ∞ (pipul)	d6 = 7.0	n4 = 1.80610	ν 4 = 40.9
r7 = -9.32306	d7 = 0.3		
r8 = 24.40418	d8 = 1.3301	n5 = 1.60311	ν 5 = 60.7
r9 = -51.70650	d9 = 0.8047		
r10 = 10.49630	d10 = 10.0	n6 = 1.60311	ν 6 = 60.7
r11 = -12.17332	d11 = 1.0	n7 = 1.84666	ν 7 = 23.8
r12 = 5.56286	d12 = 1.7183		
r13 = -11.69704	d13 = 1.0	n8 = 1.84666	ν 8 = 23.8
r14 = -221.94536	d14 = 2.1568	n9 = 1.60311	ν 9 = 60.7
r15 = -8.24002	d15 = 0.3		
r16 = 10.31164	d16 = 2.3746	n10 = 1.72916	ν 10 = 54.7
r17 = -30.38097	d17 = 12.0		

r18= 20.97714	d18= 31.0029	n11=1.51633	ν 11=64.1
r19= -9.61884	d19= 1.0	n12=1.85026	ν 12=32.3
r20=-18.35394	d20= 0.3		
r21= 39.59182	d21= 1.0	n13=1.8061	ν 13=40.9
r22= ∞	d22= 25.4664	n14=1.51633	ν 14=64.1
r23= ∞	d23= 1.0	n15=1.8061	ν 15=40.9
r24=-39.59182	d24= 0.3		
r25= 18.35394	d25= 1.0	n16=1.85026	ν 16=32.3
r26= 9.61884	d26= 31.0029	n17=1.51633	ν 17=64.1
r27=-20.97714	d27= 13.9995		
r28= 20.97714	d28= 31.0029	n18=1.51633	ν 18=64.1
r29= -9.61884	d29= 1.0	n19=1.85026	ν 19=32.3
r30=-18.35394	d30= 0.3		
r31= 39.59182	d31= 1.0	n20=1.8061	ν 20=40.9
r32= ∞	d32= 25.4664	n21=1.51633	ν 21=64.1
r33= ∞	d33= 1.0	n22=1.8061	ν 22=40.9
r34=-39.59182	d34= 0.3		
r35= 18.35394	d35= 1.0	n23=1.85026	ν 23=32.3
r36= 9.61884	d36= 31.0029	n24=1.51633	ν 24=64.1
r37=-20.97714	d37= 13.9995		
r38= 20.97714	d38= 31.0029	n25=1.51633	ν 25=64.1
r39= -9.61884	d39= 1.0	n26=1.85026	ν 26=32.3
r40=-18.35394	d40= 0.3		
r41= 39.59182	d41= 1.0	n27=1.8061	ν 27=40.9
r42= ∞	d42= 25.4664	n28=1.51633	ν 28=64.1
r43= ∞	d43= 1.0	n29=1.8061	ν 29=40.9
r44=-39.59182	d44= 0.3		
r45= 18.35394	d45= 1.0	n30=1.85026	ν 30=32.3
r46= 9.61884	d46= 31.0029	n31=1.51633	ν 31=64.1
r47=-20.97714	d47= 7.004		